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Control of Insects in Fourteen Thousand Corn Bins[1]

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In the fall of 1937 a preliminary survey of ear corn in the field and in farmers' cribs in Illinois indicated grain insects abundant. During the fall of 1938 further increases occurred. In 1938 there was a large carry-over of ear corn on farms through the government loan program. In the fall of 1939 in Illinois, farmers delivered to the Commodity Credit Corporation 22,711,223 bushels of shelled corn that were stored in 10,734 steel bins. During the fall of 1940 an additional 7,620,000 bushels were delivered, bringing the total number of steel storage units in Illinois up to 14,544.

Within 30 days after delivery, heating of the grain in some bins was being caused by insects. Active work on control of these insects was started in the fall of 1939. This was expanded until it required the time of three men by the summer of 1940.

SCOPE OF THE WORK.[3]—Early work included a survey to determine the extent of infestation. Wide differences were apparent. Twelve representative counties were selected for a study of insect control problems. Certain bins within these counties were chosen as research units, and the changes in insect population in these bins have been followed since 1939. These studies have yielded much information on insect populations and cycles, and also on temperature, moisture, and physical changes in the corn. (Of the experimental bins originally selected for study, only two groups remain that have not been treated for insect control.) Men in charge of the Commodity Credit Corporation steel bin storage units have made periodic routine observations on hundreds of bins. These observations have been especially valuable in directing the routine insect control program in the 14,544 bins within the state.

INSECTS IN SHELLED CORN.—Whole kernel damage in shelled corn is relatively unimportant. Only when insects become abundant do they induce conditions injurious to the grain. These conditions can be associated with respiration, development of heat and moisture, and condensation of moisture. Depositions of moisture are followed by molding and excessive spoilage, particularly in the center of the grain surface. It has been demonstrated that heavily infested grain that is not badly molded will return to normal condition after the insects have been destroyed, or removed by mechanical means.

INSECT DEVELOPMENT.—Data indicate that some insect infestations develop in corn stored on the ear. When the corn is shelled and stored in 2000 bushel steel bins, the insect population cycles proceed at speeds which depend on factors of moisture, amounts of cracked corn and foreign material, and the degree of insect infestation in the corn as it is brought in from the farm cribs. It has been demonstrated that only high quality, clean, shelled corn can be held in such storage for as long as 2 years in any part of Illinois without serious insect damage. Northern Illinois is in about the same latitude as Marblehead, Massachusetts, and southern Illinois in that of Richmond, Virgnia.

The indian meal moth. *Plodia interpunctella* (Hbn.), is a widely distributed shelled corn pest, at times causing serious damage to surface grain.

The angoumois grain moth, *Sitotroga cerealella* (Oliv.), caused severe damage in

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[3] Fumigation data given in this paper represent a part of a corn storage project conducted in cooperation with the United States Department of Agriculture, Bureau of Entomology and Plant Quarantine; Agricultural Adjustment Administration; and Commodity Credit Corporation. The following men employed by these agencies contributed portions of the data presented: T. F. Winburn, J. M. Magner, and E. V. Dabney.

the southern area, with only moderate damage in the central Illinois corn belt. Damage has been confined thus far to the first year after shelled corn was in storage.

The rice weevil, *Sitophilus oryza* (L.), was distributed throughout Illinois bins during the first year of shelled corn storage but was largely killed out by winter temperatures.

The granary weevil, *Sitophilus granarius*, (L.), has a wide distribution but has not been so destructive as expected in the steel bins. It has survived all winter conditions.

The rust-red flour beetle, *Tribolium castaneum* (Hbst.), is generally distributed and causes occasional severe heating in shelled corn. This insect has been difficult to control in heavily infested bins.

The flat grain beetles, *Laemophloeus ferrugineus* Steph. and *L. minutus* Oliv.; the saw-toothed grain beetle, *Oryzaephilus surinamensis* (L.); the foreign grain beetle, *Ahasverus advena* (Waltl.); the hairy fungus beetle, *Typhaea stercorea* (L.); and the cadelle, *Tenebroides mauritanicus* (L.), all widely distributed, either alone or in combination with other species, cause the most acute problems in shelled corn storage. Several other species are of undetermined importance.

New as pests of corn in storage in Illinois are *Cyneaus angustus* (Lec.) and *Platydema ruficorne* (Sturm.).

A two-year study of the life cycle of insects associated with shelled corn in steel bins indicates that, with the exception of the rice weevil, all species known to occur in the state will survive Illinois winters in the 2000 bushel steel bins.

INSECT CONTROL.—Cleaning of the shelled corn in the bins was soon recognized as an important step in reconditioning shelled corn. Grain meeting a No. 3 commercial grade as received by the Commodity Credit Corporation (CCC) was in many cases too dirty to permit effective fumigation for insect control. Machinery was developed to move and reclean shelled corn and return the grain to a clean bin. Fumigations have controlled insects in recleaned corn.

FUMIGATION.—All county Agricultural Adjustment Administration units in Illinois that have bins of shelled corn in their custody have crews of men responsible for the care of this corn. These men are charged with monthly inspections, cleaning, and fumigation of the bins. Each trained crew is equipped with a power sprayer, gas masks, and a working knowledge of requirements for successful insect control and personal safety. County crews all use a single, approved fumigant.

USE OF OIL.—As all of the fumigants in use for grain fumigation are heavier than air, some difficulty has been experienced in obtaining a satisfactory kill in the top 1 to 2 inches of corn in the bins and in preventing rapid reinfestation of the top layer by insects entering the bin through the ventilator and openings under the eaves. To overcome this, mineral oils have been used with several fumigants. They mix readily with all mixtures that include an oil solvent. The addition of from 2 to 3 quarts of mineral oil to the fumigant for each thousand bushels of shelled corn has not reduced the toxicity of the mixtures. This amount of oil deposited on the grain surface has afforded excellent control of the indian meal moth and destroyed other insects that came in contact with the layer of oiled kernels. Oil as used in these experiments has not altered the grade of the corn in commercial trade.

EXPERIMENTAL FUMIGATION.—After a satisfactory method of conducting fumigation experiments in the steel bins had been worked out, repeated tests were made. This uniformity of procedure has permitted a rapid evaluation of fumigating mixtures. All data discussed in this paper are based on tests conducted in representative steel bins, each containing about 2000 bushels of shelled corn. Results are based entirely on six or more check cells, each containing live grain insects, inserted into the grain in each test bin.

PREPARATION OF TEST BINS.—The grain surface was leveled to the upper edge of the side walls or below this point if the volume of grain permitted. All compacted areas on the surface were broken to permit a more even penetration of the fumigating gases downward through the grain.

A group of six gelatine cells containing live insects was placed equidistantly along an 11-foot brass grain probe. This probe was forced downward to the bottom of the bin in such a position that the lower cell would be located about 6 inches from the floor in the center of the bin. The upper end of the probe was entirely buried in the grain, which would locate the top cell about 6 inches below the grain surface

at from 4 to 6 feet from the center of the bin. The other cells would lie in a straight line between the lower and upper cell. All liquid fumigants were coarsely sprayed over the grain surface.

Treated bins were quickly closed and left undisturbed for 7 to 10 days, after which time they were opened and the brass probe containing the test cells of insects was removed for the purpose of counting the insects which survived.

TEMPERATURE OF BINS.—An extensive study has been made of the range of temperature within a 2000-bushel bin of shelled corn. The points of high and low temperature shifted with the seasons and lagged considerably behind the outdoor temperatures. During the summer months at the time fumigation tests were conducted, the coolest point was on the floor in the center of the bin. At 6 feet above the floor it was found that the temperature approaches the average of the four temperatures measured at the floor, 3, 6, and 9 foot levels. The average for the four varied about −2 degrees from the 6 foot reading shown in table 1. This temperature represents a probable average of the bulk of the grain in the central portion of a 2000-bushel steel bin. Near the upper surface and along the sides the grain was probably equal to or above the outside temperature for the particular day a given group of fumigations was conducted.

INSECTS IN FUMIGATION.—All insects used in the tests were obtained from a mixed culture of grain insects breeding in wheat at the Urbana laboratory. In preparation for a fumigation the wheat was screened to obtain enough insects to supply about 90 live insects per cell for the required numbers of cells. The insects along with about an equal volume of wheat were thoroughly mixed. About an ounce of wheat and insects was loaded into each cell. The cells were described in the JOURNAL OF ECONOMIC ENTOMOLOGY (Farrar 1942).

A supply of cells thus prepared was carried to the location of the bins and divided into groups of six cells for each 11-foot grain probe. The probes were placed in experimental bins and left for 24 hours to come to equilibrium with the grain temperature before fumigation. One or more probes placed in an untreated bin were used for comparison with the survival of insects in all fumigated bins. The final comparison between control and treatment was the actual number of live insects found in six untreated cells compared with those in six treated cells from a fumigated bin. The actual numbers of each species did vary through the season. The use of large numbers of test insects was considered as more favorable to the uniformity of experimental procedure than an attempt to select a relatively small number of insects for each test.

In table 1 the results have been averaged to show the numbers of each species that survived as compared with a similar group of control insects. These average numbers have been selected as preferable to an attempt to standardize these figures further.

SURVIVAL IN FUMIGATION.—Although routine fumigations were made with a single test probe (six cells) per bin, as many as six probes were often used in a single bin to determine the distribution of kill within the grain mass. Probes forced horizontally through the shelled corn gave results comparable with those in the vertical probes. With the more effective fumigants kill has been obtained in all parts of the bin where the test cells were placed.

In spite of records of complete kill in all test cells, it was found in turning the corn in recently treated bins that in some cases a few of the insects in the corn survived fumigation. The cause of this survival is not known. They probably had some environmental protection not afforded insects within test cells. In most cases, however, the use of adequate dosages in the fumigation of shelled corn reduced the insect population to such small numbers that approximately one year was required by them in again attaining destructive abundance.

RESULTS OF FUMIGATION.—The performance of 12 fumigation mixtures is given in table 1. Each has been tested under relatively uniform bin conditions in the field by standardized procedure. All materials were subjected to similar conditions of exposure. In the performance of a fumigant isolated cases of survival are reflected in the average shown in table 1 (as in the average of 0.5 live granary weevil in 50 experiments with *Dowfume Br 10* at 2 gallons; in this instance the entire survival was found in a single cell of one experiment).

The original data show many experi-

Table 1.—Performance of 12 fumigants tested in steel bins, each containing approximately 2000 bushels of shelled corn, Illinois, 1939–41.

Number of Tests	Amount of Fumigant 1000 Bu.	Average Temperature in Center of Bin 6 Ft. from Floor	Average Number of Live Insects in Six Cells after Fumigation (First Figure) Compared with Number in Unfumigated Control Cells (Second Figure)							
			Rust-red flour beetle	Rice weevil	Granary weevil	Lesser grain borer	Saw-toothed grain beetle	Flat grain beetle	Beetle larvae	Hymenop-terous parasites
Carbon bisulphide										
2	1½ gal.	64° F.	0-*11½*	1-*110*	0-*5*	0-*632*	0-*27*	0-*108*	0-*42*	0-*0*
1	2½ gal.	69	0-*75*	0-*149*	0-*7*	0-*164½*	0-*17*	0-*12*	0-*55*	0-*0*
3	3 gal.	69	1-*89*	.7-*70*	0-½	0-*214*	0-*7*	.7-*74*	0-*51*	0-*0*
2	4 gal.	59	0-*55*	0-*147*	0-*9*	0-*177*	0-*16*	0-*26*	0-*96*	0-*0*
***Dowfume* 75—ethylene dichloride–carbon tetrachloride (3-1)**										
2	1 gal.	—	23-*195*	21-*61*	75-*134*	3-*50*	0-*15*	11-*151*	15-*35*	1-*23*
1	2 gal.	68	57-*161*	39-*114*	33-*42*	289-*655*	55-*191*	41-*157*	16-*14*	2-*0*
1	3 gal.	54	30-*146*	3-*14*	0-*0*	71-*276*	0-*6*	19-*90*	1-*46*	1-*8*
9	4 gal.	57	10-*120*	3-*27*	.2-*9*	14-*297*	.3-*45*	5-*85*	3-*23*	.1-*2*
21	5 gal.	69	1-*152*	.6-*109*	4-*27*	9-*561*	.2-*123*	.1-*110*	1-*44*	.1-*0*
30	6 gal.	63	1-*69*	4-*148*	.1-*1*	2-*185*	0-*3*	.1-*96*	.2-*27*	.1-*0*
1	7 gal.	63	1-*55*	5-*147*	0-*9*	26-*177*	0-*16*	0-*26*	6-*96*	1-*0*
***Dowfume Br 5*—ethylene dichloride–carbon tetrachloride (3-1)–methyl bromide 5 per cent**										
2	5 gals.	72	.5-*100*	0-*27*	0-*1*	0-*283*	0-*0*	0-*103*	0-*46*	0-*0*
***Dowfume Br 10*—ethylene dichloride–carbon tetrachloride (3-1)–methyl bromide 10 per cent**										
20	1 gal.	80	5-*64*	.7-*99*	4-*49*	32-*152*	.4-*6*	.9-*89*	2-*22*	0-*2*
14	1½ gal.	70	.6-*96*	.2-*83*	4-*148*	3-*167*	0-*5*	0-*91*	.1-*32*	.1-*2*
50	2 gal.	73	0-*92*	0-*124*	.5-*60*	0-*187*	0-½	.1-*150*	.1-*32*	.1-*6*
5	3 gal.	—	0-*39*	0-*139*	0-*2*	0-*192*	0-½	0-*69*	0-*2*	0-.*5*
***Dowfume Br 15*—ethylene dichloride–carbon tetrachloride (3-1)–methyl bromide 15 per cent**										
1	1 gal.	—	41-*153*	1-*71*	1-*3*	9-*110*	0-*38*	4-*20½*	14-*30*	0-*0*
1	1½ gal.	—	0-*153*	0-*71*	0-*3*	0-*1101*	0-*38*	0-*20½*	0-*30*	0-*0*
2	3 gal.	73	0-*100*	0-*27*	0-*1*	0-*283*	0-*0*	0-*103*	0-*46*	0-*0*
***Dowfume Br 10s*—propylene dichloride–carbon tetrachloride (3-1)–methyl bromide 10 per cent**										
2	1½ gal.	84	2-*55*	0-*40*	0-*25*	0-*77*	0-*10*	0-*37*	0-*27*	0-*0*
22	2 gal.	85	0.1-*111*	0-*78*	0-*31*	0-*56*	0-*7*	0-*87*	0-*36*	0.1-*8*
Methyl bromide										
4	2 lbs.	67	44-*42*	119-*47½*	.5-*0*	516-*62½*	30-*18*	30-*24*	13-*9*	.8-*3*
9	3 lbs.	70	31-*42*	49-*47½*	1-*0*	222-*62½*	18-*18*	10-*24*	38-*9*	.3-*3*
3	3½ lbs.	63	49-*100*	.7-*27*	1-*1*	59-*283*	.7-*0*	31-*103*	15-*46*	0-*0*
15	4 lbs.	66	23-*57*	10-*245*	7-*4*	71-*416*	3-*9*	18-*77*	8-*17*	0-*3*
10	5 lbs.	64	33-*81*	5-*78*	.7-*2*	51-*273*	2-*3*	11-*78*	83-*36*	0-.*3*
Chloropicrin (nitrotrichloro–methane) in 1 gal. CCl_4										
2	1 lb.	70	0-*101*	0-*32*	0-*2*	0-*233*	0-*3*	0-*98*	0-*23*	0-*0*
12	2 lbs.	75	0-*58*	0-*143*	0-*15*	0-*323*	0-*7*	0-*173*	0-*15*	0-*3*
4	3 lbs.	71	0-*121*	0-*51*	0-*2*	0-*667*	0-*20*	0-*151*	0-*26*	0-*0*
3	4 lbs.	77	0-*153*	0-*71*	0-*3*	0-*1101*	0-*38*	0-*20½*	0-*30*	0-*0*
Ethide*-1, 1 dichloro-1-nitroethane in 1 gal. CCl_4 or *Dowfume 75										
9	1 lb.	76	12-*185*	2-*58*	21-*119*	4-*65*	.7-*14*	4-*145*	7-*32*	3-*20*
9	1½ lbs.	78	5-*183*	.8-*58*	4-*119*	.3-*65*	.2-*14*	.6-*145*	1-*32*	.3-*20*
8	2 lbs.	67	2-*120*	0-*63*	2-*18*	.1-*93*	0-*4*	0-*120*	.1-*30*	0-*3*
5	3–4 lbs.	72	0-*101*	0-*29*	0-*2*	0-*251*	0-*1*	0-*101*	0-*39*	0-*0*
Carbon tetrachloride–carbon bisulphide (4-1)										
4	5–6 gal.	64	1-*92*	3-*28*	.5-*3*	16-*289*	0-*3*	1-*134*	5-*30*	0-*0*
***Weevilcide*, commercial mixture**										
7	1½–2½ gal.	67	.8-*86*	3-*124*	1-*8*	31-*426*	1-*20*	3-*39*	10-*52*	.1-*0*
8	3–4 gal.	72	3-*109*	8-*110*	.5-*6*	39-*861*	3-*27*	3-*112*	6-*53*	0-*0*
5	5–8 gal.	71	4-*51*	9-*129*	.2-*9*	12-*154*	.8-*14*	3-*24*	9-*80*	0-*0*
***Tetrafume*, commercial mixture**										
5	1½–1½ gal.	70	.4-*75*	12-*149*	5-*7*	9-*164*	0-*17*	.6-*12*	7-.*55*	0-*0*
4	2–4 gal.	76	4-*153*	5-*71*	.5-*3*	55 *1101*	3-*38*	3-*20½*	4-*30*	.7-*0*

ments with a complete kill, except for isolated cases of survival. Cases of failure to kill were associated with the condition and structure of the grain mass fumigated. It is important to note that large numbers of experiments revealed these cases in which the insects exhibited abnormal reactions to fumigation procedures. The over-all results of many trials of a fumigation mixture must be considered in evaluating its performance under bin conditions.

FUMIGATING MIXTURES[4].—Carbon bisulfide gave excellent control at dosage levels of 1½ gallons (15.75 lbs.) or more per 1000 bushels.

Mixtures of carbon tetrachloride, 80 per cent, and carbon bisulfide, 20 per cent, gave good kills at a dosage of 5 gallons (63.7 lbs.) or more per 1000 bushels.

Chloropicrin had excellent toxic properties when combined with a carrier such as carbon tetrachloride. It gave staisfactory kills at 1 or more pounds of liquid (chloropicrin) in 1 gallon (13.3 lbs.) of carbon tetrachloride per 1000 bushels of grain.

Ethide was not so toxic as chloropicrin, but performed in a satisfactory manner at 2 pounds of liquid in 1 gallon (13.3 lbs.) of carrier, such as carbon tetrachloride.

Ethylene dichloride–carbon tetrachloride (3–1) (*Dowfume 75*) was satisfactory at dosage levels of 5 gallons (56 lbs.) or more per 1000 bushels. This mixture has many desirable properties as a grain fumigant.

Ethylene dichloride–carbon tetrachloride (3–1)–methyl bromide. These mixtures include a group of very toxic materials. Only limited tests were conducted with the mixtures containing 5 and 15 per cent of methyl bromide. Although these two mixtures were toxic at the dosages tested, the 5 per cent mixture does not represent an efficient saving in the ethylene dichloride–carbon tetrachloride (3–1) mixture, and the 15 per cent mixture boils at a point too low for general handling as a fumigant.

[4] Some chemicals used in these tests were generously furnished by several manufacturers, including: Commercial Solvents Corp. (*Ethide*); Douglas Chemical & Supply Co. (*Tetrafume*); Dow Chemical Co. (*Dowfume 75*; *BR 5–10–15–10S*); Innis, Speiden & Co. (Chloropicrin); Weevilcide Co. (*Weevilcide*).

The 10 per cent methyl bromide mixture, and the special propylene dichloride-10 per cent methyl bromide mixture perform in a very similar manner under field conditions. Their most objectionable features are a potential high toxicity to the fumigating crew. A suitable mask must be used with either mixture. At dosage levels of 2 gallons (23 lbs.) or more per 1000 bushels, both gave consistently high kills of insects.

Methyl bromide used alone at different dosages up to 5 pounds per 1000 bushels was not a satisfactory grain fumigant. The failure of this chemical was due apparently to a lack of even distribution of the gas within the grain mass.

Weevilcide and *Tetrafume* are commercial fumigants. Both fumigants were tested at dosage levels below those which gave satisfactory kills. A very limited group of tests at dosage levels above 4 gallons (51 lbs.) per 1000 bushels indicates that their performance is in the same range of toxicity as the carbon tetrachloride–carbon bisulfide (4–1 mixture) and ethylene dichloride–carbon tetrachloride (3–1) mixture.

SUMMARY.—Twelve fumigating mixtures were tested at several dosage levels to determine their respective toxicity to grain insects in steel bins. The following mixtures appear to offer the most promise as highly toxic fumigants for shelled corn in steel bins:

Ethylene dichloride–carbon tetrachloride (3–1)–methyl bromide, 10 per cent.

Propylene dichloride–carbon tetrachloride (3–1)–methyl bromide, 10 per cent.

Ethide–carbon tetrachloride and chloropicrin–carbon tetrachloride.

Satisfactory if sufficient dosage is used are:

Ethylene dichloride–carbon tetrachloride (3–1); carbon bisulfide; carbon tetrachloride–carbon bisulfide (4–1), and similar proprietary mixtures.

Methyl bromide when used alone was not a satisfactory grain fumigant in steel bins.

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Free Nicotine in Arsenical and Cryolite Dust Mixtures

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During the last several years attempts have been made to make a concentrated nicotine dust that could be combined with calcium arsenate, cryolite, and other insecticides. This was attempted by adsorbing 95 per cent free nicotine on various types of clays and then using enough of the clay to furnish 1 per cent of free nicotine in the finished dust. Some of these clays were satisfactory in that the final mixture gave adequate control of the cotton aphis. The principal fault of this work was that the clays would adsorb not more than 5 or 6 per cent of the free nicotine. Because of this it was necessary to use a rather large proportion of the concentrated nicotine dust with the calcium arsenate. With the development of *Black-leaf "10"* this handicap has been overcome since this material carries 10 per cent actual nicotine, thus reducing the amount of diluent needed in the insecticide mixtures.

This concentrated nicotine dust is prepared by adsorbing pure nicotine alkaloid on finely divided tobaco dust. The commercial product analyzes 10 per cent nicotine.[1]

The experimental use of insecticide-fungicide dust mixtures on cucumbers has greatly increased the yield and quality of fruit as compared with the recommended bordeaux-lead arsenate-nicotine sulfate spray.

The destructive pests of cucumbers in Louisiana are the cotton aphid, *Aphis gossypii* Glover; the pickleworm, *Diaphania nitidalis* (Stoll.); the melon worm, *D. hyalinata* (Linne); and the 12-spotted, banded and striped diabrotica beetles. The aphid and the pickleworm are the two most important ones. Unless the aphids are partially controlled, it is impossible to grow cucumbers. An average of 25 per cent loss of fruit is sustained annually as a result of pickleworm injury using the recommended bordeaux-lead arsenate-nicotine sulfate spray.

Cucumber Experiments.—The first experiments, using a combination dust of cryolite, basic copper sulfate, and nicotine, on cucumbers were encouraging except for the fact that the nicotine in the mixture did not give any control of the aphids. Both free nicotine and nicotine sulfate were tried but without positive results. Control of the aphids in these experiments was secured by a separate spray of nicotine sulfate. It appeared that the nicotine in the mixture was adsorbed by the other materials present and was released so slowly that it was ineffective. Also it was shown in laboratory tests that nicotine was released very slowly from cryolite-basic copper sulfate-nicotine mixtures.

This disadvantage was overcome in the 1941 experiments when the source of nicotine in the dust was *Black-leaf "10."* The nicotine content of the dust mixture was 1 per cent. This proved adequate to give perfect control of the aphids throughout the experiment. A total of 10 applications was made of which eight contained nicotine. In the other two applications nicotine was omitted because of the absence of aphids.

The dust formula which proved most effective and practical was cryolite, 15 to 33 per cent; copper, 7 per cent, derived from basic copper sulfate; nicotine, 1 per cent, derived from *Black-leaf "10"*; and diluent, *Pyrax ABB*.[2]

Other aphicides were tried in the mixture but none was suitable. These were pyrethrum, rotenone, and other forms of nicotine. The dusts containing 1 per cent rotenone gave excellent aphid control in the 1941 experiments, but failed to control the aphids in the 1940 tests. The rotenone did not give as efficient control of the pickleworm and diabroticas as was secured from cryolite.

The yield of cucumbers from dusted plots was nearly double that from plots treated with the bordeaux-lead arsenate-nicotine sulfate spray. The plots which received the dust without any nicotine yielded only half as much as the spray plots, and only a third as much as the dust plots receiving nicotine.

Therefore, experiments have shown that with a suitable combination dust, the yield of fruit was doubled over the stand-

[1] Manufactured by the Tobacco By-Products and Chemical Corp.

[2] The mineral pyrophyllite, pH 6.9. Product of R. T. Vanderbilt Co.

ard treatment, the loss from the pickleworm and melonworm was eliminated entirely, and control of the aphids and diseases of cucumbers were accomplished in one operation (Table 1).

SQUASH EXPERIMENTS.—In a similar experiment concerning the control of aphids, melonworm, pickleworm, and diabroticas on squash, it was found that a similar dust to that above except containing 0.5 per cent nicotine derived from *Black-leaf "10"* gave a significant increase in yield of fruit over plots where nicotine was not included in the mixture. These plots produced 3700 pounds of fruit free of worms per acre. A third dust in the series contained 0.5 per cent nicotine derived from 95 per cent free nicotine. These plots produced 2000 pounds of fruit per acre, and a similar yield was obtained from the plots in which nicotine was not included in the dust. The yield of fruit from the plots receiving *Black-leaf "10"* in the treatment was significantly higher than the yields from these other two plots. This field was never infested with aphids. Therefore the increase in yield obtained through the use of *Black-leaf "10"* in the mixture cannot be attributed to aphid control. Counts were not made, but it was observed during the course of the experiment that these plots maintained a greater number of blossoms than other plots. It is possible that additional protection of the flowers from attack by the pickleworm was given these plants resulting in a greater set of fruit. Or the difference in yield may have resulted from the heavier rate of application of this dust.

Analysis of variance showed that *Black-leaf "10"* was significant over rotenone in the cryolite-copper dust and the cryolite-copper dust without nicotine in reducing the loss caused from pickleworm infestation (Table 1).

Laboratory experiments.—A carefully controlled series of laboratory tests was conducted on the cotton aphid, using

Table 1.—Result of several insecticide treatments on cucumbers and squash with statistical analyses—1941.

TREATMENT[4]	AVERAGE RATE PER ACRE	YIELD (POUNDS)	FRUIT WORMY	EQUIVALENT ANGLE	PLANTS INJURED BY APHIDS
Cucumbers					
Cryolite, 33%; copper, 7%[1]	13.75 lbs.	20.53	1.80%	13.94	72.5%
Cryolite, 33%; copper, 7%; nicotine,[2] 1%	14.10 lbs.	59.27	0.00	0.00	0.8
Bordeaux, 8–8–100; lead arsenate, 3 lbs. per 100 gal.; nicotine sulfate, 1–800	—	38.53	23.12	147.19	1.6
Rotenone, 1%; copper, 7%	14.84 lbs.	77.80	6.66	74.22	0
Cryolite, 15%; copper, 7%; Nicotine, 2%[3]	14.37 lbs.	72.31	0.77	14.26	0
Minimum difference required for significance		19.12		20.21	—
Squash					
Cryolite, 33%; copper, 7%; Nicotine, ½ per cent[3]	13.00 lbs.	126.37	8.6	94.18	none
Cryolite, 33%; rotenone,1%; Copper, 7%	11.60 lbs.	97.75	23.8	145.56	none
Cryolite, 33%; copper, 7%; Nicotine, ½%[3]	9.07 lbs.	84.75	18.9	111.23	none
Cryolite, 33%; copper, 7%	7.60 lbs.	88.12	23.1	141.55	none
Check (no treatment)	—	54.87	46.2	218.11	none
Minimum difference required for significance		31.38		45.99	

[1] Copper derived from basic copper sulfate (used for disease control).
[2] Derived from *Black-leaf "10"*.
[3] Derived from 95 per cent free nicotine.
[4] *Pyrax ABB* was used as a diluent for all the dust mixtures.

Black-leaf "10" in a number of different diluents. Each dust contained 2 per cent of nicotine. Ten replications were made of each material involving a total of approximately 800 insects per insecticide. The purpose of these tests was to learn the compatibility of *Black-leaf "10"* with the different materials. The nicotine was effective and compatible with all the materials used. They are rated in order of effectiveness as follows: Perry clay, bancroft clay, leaching clay, tobacco stem dust, *Pyrax ABB*, wheat flour, calcium hydroxide, walnut-shell flour, calcium arsenate, and cryolite. There was very little difference in toxicity among the above named diluents excepting cryolite, which was only half as great as the others, and calcium arsenate, which was intermediate in toxicity between cryolite and the other diluents.

Cotton aphids.—A field experiment which involved the use of calcium arsenate plus an aphicide for the control of cotton aphids along with the boll weevil control was conducted in the Saint Joseph area in 1941. Calcium arsenate plus one per cent nicotine derived from *Black-leaf "10"* was compared with calcium arsenate plus 0.5 per cent rotenone[1] and 10 per cent sulphur; calcium arsenate plus 10 per cent sulfur and 0.2 per cent pyrethrins,[1] and calcium arsenate alone. Pyrethrum gave no control of the aphids; rotenone gave partial control, but complete control was secured from the nicotine-calcium arsenate treatment. There was an increase of 290 pounds of seed cotton per acre in the nicotine plots as compared to the calcium arsenate-rotenone plots, a similar increase compared to the pyrethrum plots, and an increase of 416 pounds seed cotton as compared to the plots receiving only calcium arsenate. This increase in yield of seed cotton in the calcium arsenate-nicotine plots over the other treatments is shown to be significant (Table 2).

A separate field experiment was conducted where calcium arsenate plus 1 per cent nicotine from *Black-leaf "10"*, calcium arsenate plus 1 per cent nicotine from nicotine sulfate, and 1 per cent nicotine-lime dust were compared for effectiveness in controllling the cotton aphid. The aphid count was the criterion of effectiveness in this experiment. Analysis of variance showed the three treatments were equal in reducing the aphid population.

Table 2.—Average infestation of cotton aphids and boll weevils, and average yield of seed cotton with statistical analyses—Saint Joseph, Louisiana, 1941.

Treatment	Dust Per Acre	Aphids Per Square Inch		Boll Weevil		Yield of Seed Cotton Pounds	
		Average	Square Root	Squares Punctured	Equivalent Angles	Per Plot	Per Acre
Untreated check	—	10.4	3.21	60.4%	52.60	31.74	1269.60
Calcium arsenate, sulphur 10%, rotenone 0.5%	12.1 lbs.	7.4	2.67	32.6	34.00	34.60	1384.0
Calcium arsenate	13.3	11.8	3.42	28.9	31.84	31.46	1258.40
Calcium arsenate, Nicotine 1.0%	13.6	0.6	0.77	25.2	29.80	41.86	1674.40
Calcium arsenate, sulphur 10%, pyrethrins 0.2%	11.2	13.5	3.65	41.4	39.32	34.20	1368.00
Minimum difference required or significance			0.31		.86	5.89	

CONCLUSIONS.—There are four conclusions which are evident from the experimental results secured from the use of this concentrated nicotine dust mixed with various diluents and insecticides.

1. That a combination with cryolite and basic copper sulfate gave perfect control of aphids and the other insects attacking cucumbers, and that the yield of fruit was significantly greater than that secured from the plots treated according to the established method of control, with bordeaux, lead arsenate, and nicotine sulfate spray.

2. That the yield of squash was nearly doubled where this form of nicotine was

[1] The rotenone was secured from 5 per cent derris; pyrethrins were secured from *Pyrocide*, 2 per cent pyrethrins adsorbed on clay.

used in a dust treatment which consisted of cryolite, basic copper sulfate, nicotine and *Pyrax*, as compared to the same treatment where 95 per cent free nicotine was used or where no nicotine was used in the dusts.

3. That it was the most effective aphicide used in calcium arsenate mixtures in controlling the cotton aphid in field experiments, and that it was as effective as nicotine sulfate in calcium arsenate for reducing the aphid population.

4. That in laboratory experiments it was compatible with and effective in killing cotton aphids when tested with 10 different diluents.—5-22-42.

Insecticide Tests for Cotton Aphid and Boll Weevil Control During 1941

I. J. BECNEL and E. H. FLOYD, *Louisiana Agricultural Experiment Station, University*

Experiments in the control of the cotton aphid, *Aphis gossypii* Glov. and the cotton boll weevil *Anthonomis grandis* Boh. were conducted at Saint Joseph and Baton Rouge, Louisiana during the summer of 1941. The cotton aphid usually appears at these locations every year and frequently the injury during severe outbreaks is so great that considerable early defoliation occurs. The object of this experiment was to study the effect of aphids on yield of seed cotton in a boll weevil control program and to determine the effectiveness of several aphicides in combination with calcium arsenate.

PLOTS AND TREATMENTS, SAINT JOSEPH—Each plot including buffer areas was 15 rows in width and of sufficient length to be one-fourteenth acre in area. The entire plots were treated and the buffers included the three outside rows and ample areas at the ends of each plot. The plots were arranged in a latin square which included a check and four treatments. The plots for treatment received the following insecticides: a dust containing calcium arsenate, 10 per cent sulphur and 0.5 per cent rotenone;[1] calcium arsenate;[2] a dust containing calcium arsenate, and 1.0 percent nicotine;[3] and a dust containing calcium arsenate, 10 per cent sulphur and 0.2 per cent pyrethrins.[4]

[1] Rotenone derived from Derris containing 5.0 per cent rotenone. Three hundred and twenty-five mesh dusting sulphur was used in mixtures containing sulphur.

[2] Calcium arsenate analysis as printed on container:
Active ingredients: Tri calcium arsenate 70%.
Inert ingredients: 30%.
Total arsenic (expressed as metallic arsenic) not less than 26.1%; equivalent to 40% arsenic oxide. Arsenic in water soluble form (expressed as per cent metallic arsenic) not less than 0.5%; equivalent to 0.75% arsenic oxide.

[3] Nicotine derived from *Black leaf "10"* dust: Active ingredient: Nicotine alkaloid 10%, Inert ingredients: Not more than 90%.

[4] Pyrethrins derived from *Pyrocide* (oil extract of pyrethrum adsorbed on clay and containing 2.0% pyrethrins.

The calcium arsenate used for all treatments was obtained from the same source. All dusts were applied with hand rotary dust guns during the late afternoon and accurate records of the amount of dust used for each application were obtained. The plots for treatment were dusted on July 25, July 30, August 4, August 8, and August 18, 1941.

BATON ROUGE—Each plot excluding buffer areas was 10 rows wide and of sufficient length to be one-nineteenth acre in area. It was necessary to cut out every other row in each plot prior to beginning treatments because of extreme rank growth and crowding of plants. This allowed sufficient buffer areas between plots. The plots were arranged in a latin square and received treatments identical to the treatments used at Saint Joseph. Plots for treatment were dusted during the late afternoons on July 18, July 22, July 27, August 1, August 7, and August 20, 1941.

RECORDS.—The infestation records were begun after the first treatments were applied and were made at approximately 5 day intervals at St. Joseph and at more or less irregular intervals at Baton Rouge. Boll weevil infestation records included the number of punctured squares per 100 consecutive squares near the middle of each plot. The cotton aphid records were obtained by examining 1 square inch near the center of the lower surface of the fourth leaf from the top on 100 plants located near the middle of each plot and selected at random. Four records were obtained during the effective treatment period in each experiment. The yield per plot was the amount of seed cotton obtained on one-fortieth acre at Saint

Table 1.—Average infestation of cotton aphids and boll weevils, and average yield of seed cotton with statistical analyses—1941.

	Pounds Dust Used Per Acre	Aphids per Square Inch		Boll Weevil Infestation		Yield of Seed Cotton Pounds	
		Average	Square Root	Per Cent Squares Punctured	Equivalent Angles	Per Plot	Per Acre
Saint Joseph, Louisiana							
Untreated check	—	10.4	3.21	60.4	52.60	31.74	1269.60
Calcium arsenate, 10 per cent sulphur, 0.5 per cent rotenone	12.1	7.4	2.67	32.6	34.00	34.60	1384.0
Calcium arsenate	13.3	11.8	3.42	28.9	31.84	31.46	1258.40
Calcium arsenate, 1.0 per cent Nicotine	13.6	0.6	0.77	25.2	29.80	41.86	1674.40
Calcium arsenate, 10 per cent sulphur, 0.2 per cent pyrethrins	11.2	13.5	3.65	41.4	39.32	34.20	1368.00
Minimum difference required for significance			0.31		6.8	5.89	
Baton Rouge, Louisiana		Square Root+0.5					
Untreated check	—	2.18	1.62	60.6	52.22	45.42	862.98
Calcium arsenate, 10 per cent sulphur, 0.5 per cent rotenone	10.2	2.74	1.78	46.6	44.96	59.40	1128.6
Calcium arsenate	13.2	12.86	3.64	41.4	39.08	49.78	945.82
Calcium arsenate, 1.0 per cent Nicotine	13.2	0.72	1.06	40.2	37.96	61.86	1175.34
Calcium arsenate, 10 per cent sulphur, 0.2 per cent pyrethrins	10.2	8.66	2.99	55.8	49.74	50.80	965.20
Minimum difference required for significance			1.08		7.86	6.10	

Table 2.—Analyses of variance for experiments conducted at Saint Joseph and Baton Rouge, Louisiana.

Source of Variation	Degrees of Freedom	Square Root of Aphids Per Square Inch	Boll Weevil Infestation Equivalent Angles	Yield of Seed Cotton Pounds Per Plot
Saint Joseph				
Rows	4	0.777	372.94	56.45
Columns	4	1.060	278.93	17.87
Treatments	4	27.016**	1612.27**	353.80*
Error	12	0.749	299.97	219.54
Total	24	29.602	2546.11	647.66
Baton Rouge		Square Root+0.5		
Rows	4	1.22	282.81	13.15
Columns	4	0.33	408.45	132.67
Treatments	4	22.50**	794.94**	955.52**
Error	12	0.76	391.16	235.35
Total	24	24.81	1877.36	1336.69

Joseph and one-nineteenth acre at Baton Rouge. Small samples of seed cotton obtained at Saint Joseph were ginned and graded, in an attempt to ascertain whether the quality of the lint was affected by aphid injury.

RESULTS.—The average infestation of cotton aphids and boll weevils and the average yield of seed cotton per plot are presented in table 1. The square roots of the average aphid counts obtained at Saint Joseph were used in the analysis of variance of this data whereas the square roots plus one-half were used for the aphid data obtained at Baton Rouge. The per cent of boll weevil punctured squares recorded at each observation in both experiments were transformed to equivalent angles and the average angles were used in the analysis of variance.

In the experiment at Saint Joseph the plots treated with calcium arsenate, 1.0 per cent nicotine produced the greatest yield of seed cotton. This yield was significant over all other plots. The aphid infestations in these plots were significantly lower than that of all other plots, and the boll weevil infestations were significantly lower than that of the checks and the plots treated with calcium arsenate, 10 per cent sulphur, 0.2 per cent pyrethrins. Calcium arsenate and calcium arsenate, 10 per cent sulphur, 0.2 per cent, pyrethrins treatments resulted in aphid counts greater than counts obtained in the checks. In fact the counts obtained in the checks were significantly less than those obtained on the calcium arsenate, sulphur, pyrethrins treated plots. The aphids on plots treated with calcium arsenate, 10 per cent sulphur, 0.5 per cent rotenone were significantly less than aphids on the checks, the calcium arsenate, and the calcium arsenate, sulphur, pyrethrins plots. Boll weevil infestation on the checks was significantly greater than infestations on all treated plots. Calcium arsenate; calcium arsenate, sulphur, rotenone; and calcium arsenate, nicotine were equally effective in reducing boll weevil infestations. From table 1 it will be noted that boll weevil injury in treated plots was fairly uniform with the exception of the plots treated with calcium arsenate, sulphur, pyrethrins, which was considerably greater.

There were no appreciable differences in lint grades or length.

In the experiment at Baton Rouge the plots treated with calcium arsenate, 1.0 per cent nicotine and calcium arsenate, 10 per cent sulphur, 0.5 per cent rotenone produced significantly greater yields than any other plots and, together with the checks, had significantly fewer aphids than the other plots. The boll weevil infestations were again greatest on the checks, followed closely by the calcium arsenate —10 per cent sulphur —0.2 per cent pyrethrins, and the calcium arsenate —10 per cent sulphur —0.5 per cent rotenone treated plots. The infestations on the plots treated with calcium arsenate and calcium arsenate plus 1.0 per cent nicotine were significantly lower than infestation on plots receiving calcium arsenate, 10 per cent sulphur, 0.2 per cent pyrethrins and the untreated checks.

Table 3.—Average aphid counts at initial observations and 11 days following fifth treatment.

	Average Number Aphids per Square Inch of Leaf Surface			
	Initial Count		11 days after fifth treatments	
	St. Joseph	Baton Rouge	St. Joseph	Baton Rouge
Checks	2.3	.09	32.8	3.7
Calcium arsenate, sulphur, rotenone	2.3	.09	36.5	4.0
Calcium arsenate	2.0	.15	53.6	17.8
Calcium arsenate, nicotine	2.3	.04	1.8	1.0
Calcium arsenate, sulphur, pyrethrins	2.4	.09	54.2	14.1

From table 3 it will be noticed that the initial aphid counts were uniformly distributed over all plots for both experiments. However, the counts following the effective treatment period were considerably greater at Saint Joseph. The counts obtained at both locations were proportionately the same for each treatment. The plots treated with nicotine were infested with very few aphids and observations revealed that the plants on these plots held their foliage for a considerably longer period than plants on the other plots. This was particularly true at Saint Joseph, where nicotine treated plants continued to fruit several days after aphid injured plants had ceased.

SUMMARY.—Experiments were conducted at two locations to study the effect of calcium arsenate; calcium arsenate plus 10 per cent sulphur and 0.5 per cent rotenone; calcium arsenate plus 1.0 per

cent nicotine; and calcium arsenate plus 10 per cent sulphur and 0.2 per cent pyrethrins, upon the cotton aphid, the boll weevil and upon the yield of seed cotton and these results were analyzed statistically. The aphid and boll weevil infestations were lowest on plots receiving calcium arsenate plus 1.0 per cent nicotine in both experiments. In one experiment the aphid counts for these plots were significantly lower than counts for all other treatments, and, together with plots receiving calcium arsenate plus 10 per cent sulphur and 0.5 per cent rotenone, were significant compared with the remaining treatments in the second experiment. Boll weevils were significantly reduced by all treatments, however, the differences between treatments showed that calcium arsenate alone, calcium arsenate plus 1.0 per cent nicotine, and calcium arsenate plus 10 per cent sulphur and 0.5 per cent rotenone, were more effective than calcium arsenate plus 10 per cent sulphur and 0.2 per cent pyrethrins. In one experiment the yields from the plots treated with calcium arsenate plus 1.0 per cent nicotine were significantly greater than any other yields and, along with the plots receiving calcium arsenate plus 10 per cent sulphur and 0.5 per cent rotenone were significant as compared with the remaining treatments in the other experiment. In both experiments the calcium arsenate plus 1.0 per cent nicotine treatment resulted in an average increase over the checks of 359 pounds of seed cotton per acre; the calcium arsenate plus 10 per cent sulphur and 0.5 per cent rotenone, 168 pounds; the calcium arsenate plus 10 per cent sulphur and 0.2 per cent pyrethrins, 258 pounds; and the calcium arsenate alone, 323 pounds.—5-22-42.

Insecticides to Control Bollworm, Boll Weevil, Cotton Aphid, and Cotton Flea Hopper

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Cage toxicity tests conducted at Waco, Tex., in 1940 showed that basic copper arsenate mixed with sulfur or hydrated lime gave higher mortalities of bollworms, *Heliothis armigera* (Hbn.), boll weevils, *Anthonomus grandis* Boh., and cotton leaf worms, *Alabama argillacea* (Hbn.), than did calcium arsenate (Moreland *et al.* 1941).

During 1941 field-plot experiments using calcium arsenate, lead arsenate, basic copper arsenate, derris, and other materials were conducted at Waco for control of the bollworm, boll weevil, and cotton aphid, *Aphis gossypii* (Glov.), and at Port Lavaca, Tex., for control of the cotton flea hopper, *Psallus seriatus* (Reut.).

PLOTS, TREATMENTS, AND RECORDS.—The plots ranged from 10 to 16 rows in width and from 0.05 to 0.20 acre in area, and they were arranged in randomized blocks. The entire plots were treated The dusts were applied with single-nozzle rotary hand guns in the early morning and at approximately 5-day intervals. Only one spray was used and it was applied with a knapsack sprayer at midday at the rate of 30 gallons per acre.

Infestation records were made at about 7-day intervals on the six or eight middle rows of each plot. Records on the bollworm were made by counting the injured squares or bolls in 200 squares or bolls in each plot, those on the boll weevil by counting the weevil-punctured squares in 200 squares in each plot, those on the cotton aphid by counting the aphids on a square inch of leaf area near the center of the fourth leaf from the top of 100 plants in each plot, and those on the cotton flea hopper by counting the adult and nymphal flea hoppers on 100 main stem terminals in each plot.

The yield records were made on half the plot area, except in experiment 5, where they were made on the entire plot. In the 16-row plots three rows on each side and a portion of each end and in the

[1] Dial F. Martin, F. A. Cowan, and Howard Holbert assisted in making the field-plot records at Waco, Charles Parencia supervised the experiments at Port Lavaca, E. E. Ivy assisted in assembling field data and in preparation of the paper, J. C. Gaines made the statistical analysis, and the Division of Insecticide Investigations, Bureau of Entomology and Plant Quarantine, made the chemical analyses and particle-size determinations of insecticides.

10-row plots two rows on each side and a portion of each end were left as buffers.

The insecticides used were as follows:

Calcium arsenate—7.8 per cent water-soluble arsenic pentoxide (New York method), 41.6 per cent total arsenic pentoxide, surface mean diameter of particles 1.3 microns.

Zinc-safened calcium arsenate—2 per cent water-soluble arsenic pentoxide, 42 per cent total arsenic pentoxide, 3.7 per cent zinc oxide, surface mean diameter 0.5 micron.

Calcium arsenate and paris green (ready mixed)—7 per cent water-soluble arsenic pentoxide, 39.2 per cent total arsenic pentoxide, 4.2 per cent arsenious trioxide, 2.2 per cent copper oxide.

Calcium arsenate and zinc arsenate—5.7 per cent water-soluble arsenic pentoxide, 42.3 per cent total arsenic pentoxide, 4.4 per cent zinc oxide.

Calcium arsenate, zinc sulfate, and hydrated lime—1.7 per cent water-soluble arsenic pentoxide, 33.9 per cent total arsenic pentoxide, 3.2 per cent zinc oxide.

Lead arsenate—0.24 per cent water-soluble arsenic pentoxide, 32.5 per cent total arsenic pentoxide, surface mean diameter 0.6 micron.

Basic copper arsenate—0.05 per cent water-soluble arsenic pentoxide, 38.2 per cent total arsenic pentoxide, 55 per cent copper oxide, surface mean diameter 0.6 micron.

Micronized paris green—6.2 per cent water-soluble arsenious trioxide, 53.5 per cent total arsenious trioxide, 0.9 per cent arsenic pentoxide, 30.9 per cent copper oxide, surface mean diameter 0.8 micron.

Synthetic cryolite—84.9 per cent sodium fluoaluminate, surface mean diameter 1.9 microns.

Natural cryolite—89.1 per cent sodium fluoaluminate, surface mean diameter 2.1 microns.

Derris powder—5 per cent rotenone, 14.9 per cent total extractives.

Sulfur—325 mesh, 94.6 per cent pure.

EXPERIMENTS ON THE BOLLWORM.—At the time the treatments were started there were on an average 87 and 61 bollworm eggs per 100 terminals in experiment 1 and experiment 2, respectively. The two series of plots were adjacent in the same field. Four applications were made between July 31 and August 20. No appreciable boll weevil or cotton flea hopper damage occurred. Four weevil infestation records made between July 30 and August 22 showed that on an average 1.3 per cent of the squares were punctured. Soon after dusting began, aphids became abundant, but they were effectively controlled in all plots with a 3 per cent nicotine-lime mixture applied on August 18. To prevent leafworm defoliation and damage, the check plots were dusted on August 22 and the check and cryolite-treated plots on August 29 with a mixture of 14 per cent of paris green and hydrated lime. Cryolite was the only insecticide that did not protect the cotton from leafworms for several weeks following the last treatment for bollworm control. The results are summarized in table 1.

Table 1.—Results of experiments against the bollworm.

Treatment	Rate per Acre, Pounds	Bollworm Infestation, Per Cent		Yield of Seed Cotton per Acre, Pounds
		Injured Squares	Injured Bolls	
Experiment 1, 4 replicates				
Untreated check	—	19.3	13.6	564
Calcium arsenate	9.7	11.5	8.6	885
Lead arsenate	8.0	7.2	6.8	983
Synthetic cryolite	9.7	8.1	8.1	911
Basic copper arsenate and hydrated lime 1:1	14.8	8.1	6.8	1,103
Difference required for significance, 5% level		3.5	2.7	142
Experiment 2, 4 replicates				
Untreated check		22.5	18.6	411
Calcium arsenate 92.5% and paris green 7.5%	10.5	11.3	8.9	850
Natural cryolite	9.9	9.7	7.5	908
Lead arsenate	9.3	8.9	7.4	980
Lead arsenate spray	9.0	11.9	8.8	884
Difference required for significance, 5% level		2.3	3.2	141

In experiment 1 the mixture of basic copper arsenate and lime produced the highest yield, a gain over the check of 539 pounds. Lead arsenate was second, with a gain of 419 pounds, synthetic cryolite was third, with a gain of 347 pounds, and calcium arsenate fourth, with a gain of 321 pounds. The gain from the mixture of basic copper arsenate and lime was 218 pounds, or 68 per cent, more than the gain from calcium arsenate.

In experiment 2 the highest gain was 569 pounds from lead arsenate dust. The next highest was 497 pounds from natural cryolite. The lead arsenate spray resulted in a gain of 473 pounds which was 96 pounds, or 16.9 per cent, less than the gain from lead arsenate dust. The least gain was 439 pounds from the mixture of paris green and calcium arsenate.

BOLL WEEVIL AND COTTON APHID.—Experiments 3 and 4 were conducted in the same field and received the same treatments, but they differed with respect to size and arrangement of plots. Since the results of the two experiments were very similar, the records have been combined. When treatment was begun, 33.6 to 35.8 per cent of the squares were punctured in the various plots of experiment 3 and 24 to 28.5 per cent in experiment 4. Eight applications were made in each experiment between June 24 and August 9. Cot-

ton flea hopper infestation records showed a low population of this insect in all plots after dusting began. Three records of bollworm injury were made between July 29 and August 14. Seven records of boll weevil infestation were made between July 2 and August 14. Eight aphid infestation records were made between July 2 and August 25. The results are shown in table 2.

In experiment 5, 10 dust applications were made between July 22 and September 2, 2 of which were washed off by rains. At the time the experiment was started 11.4 per cent of the squares were punctured. Boll weevil infestation records were made on August 4, 13, and 19. Five aphid infestation records were made between August 5 and September 3. Three bollworm injury records were made between August 4 and 19. These showed light injury with practically no differences between treatments. Flea hopper infestation records showed between 3.4 and 6.9 flea hoppers per 100 terminals in the various plots.

No untreated checks were included in the experimental area, but a comparable area was selected just outside, and infestation and yield records were made thereon. The outside checks showed an average seasonal boll weevil infestation of 53.5 per cent, an aphid infestation of 0.32 aphid per square inch, and a yield of 392 pounds per acre. The results of this experiment are given in table 2.

In experiments 3 and 4 the aphid infestation was much lower and the yield much higher in the plots treated with the mixture of basic copper arsenate and sul-

Table 2.—Results of experiments against the boll weevil and cotton aphid.

Treatment	Rate of Application per Acre, Pounds	Squares Punctured by Boll Weevil, Per Cent	Aphids per Square Inch of Leaf Area Number		Squares Injured by Bollworms, Per Cent	Yield of Seed Cotton per Acre, Pounds
			Maximum	Average		
Experiments 3 and 4, 8 replicates						
Untreated check		26.5	7.6	1.4	12.9	781
Calcium arsenate	7.0	15.8	33.3	6.8	10.2	1,216
Zinc-safened calcium arsenate	6.5	16.5	24.3	4.5	8.8	1,393
Calcium arsenate and derris (0.5% rotenone)	6.9	16.9	23.8	4.0	10.2	1,173
Basic copper arsenate and sulfur 1:1	12.9	19.3	13.7	2.6	6.3	1,530
Difference required for significance, 5% level		3.3		.9	1.8	198
Experiment 5, 4 replicates						
Calcium arsenate	8.0	12.3	28.5	17.1	11.5	1,218
Calcium arsenate and nicotine sulfate (1% nicotine)	8.2	13.9	2.9	1.6	9.6	1,335
Calcium arsenate and derris (0.5% rotenone)	8.2	11.6	8.2	5.8	11.6	1,276
Calcium arsenate 85%, zinc sulfate 7.5%, and hydrated lime 7.5%	8.7	15.7	24.9	15.0	9.2	1,147
Calcium arsenate 90% and zinc arsenate 10%	8.2	13.1	28.2	16.6	10.0	1,227
Difference required for significance, 5% level				2.7		

fur than in the plots treated with calcium arsenate and derris, zinc-safened calcium arsenate, or calcium arsenate alone. It is possible that the sulfur and copper in the mixture had a slight stimulating or beneficial effect on the cotton plant. This, along with the successful control of the boll weevil and the lowering of the aphid and bollworm infestations, probably accounted for the rather remarkably higher yield.

Each insecticide used in experiment 5 gave excellent control of the boll weevil, but the only insecticide that gave adequate control of the aphid was the mixture of calcium arsenate and nicotine sulfate. In the cotton treated with the mixture of calcium arsenate and derris 3.6 times as many aphids were found as in the cotton treated with calcium arsenate and nicotine sulfate. There was no honeydew or leaf shed in the cotton receiving the nicotine treatment, whereas honeydew was noticeable and there was a little leaf shed in the cotton treated with calcium arsenate and derris. There was practically no control of aphids from the mixtures of calcium arsenate and zinc sulfate and calcium arsenate and zinc arsenate.

COTTON FLEA HOPPER.—In experiment 6 three replicates of each treatment were in one field and three in another. In one field four effective applications of the various insecticides were made between June 24 and July 18, and in the other field three effective applications were made between June 25 and July 18. When treatment was begun, there were 54.6 flea hoppers per 100 terminals. Five flea hopper infestation records were made between June 27 and July 23 after dusting began. Two boll weevil infestation records made during the season showed no punctured squares in any of the plots. Bollworm infestation records revealed only a light infestation of this insect with practically no damage. The results are shown in table 3. It will be noted that the mixture of basic copper arsenate and sulfur produced the highest yield.

Table 3.—Results of experiments against the cotton flea hopper.

TREATMENT	RATE PER ACRE, POUNDS	FLEA HOPPERS PER 100 TERMINALS	SEED COTTON PER ACRE, POUNDS
Experiment 6, 6 replicates			
Untreated check		38.3	753
Sulfur	16.1	12.3	881
Calcium arsenate and sulfur 1:2	14.5	10.6	978
Basic copper arsenate and sulfur 1:2	14.0	10.8	1,041
Micronized paris green 7.5% and sulfur 92.5%	14.8	9.5	944
Difference required for significance, 5% level		6.1	93

SUMMARY.—Basic copper arsenate mixed with sulfur or lime produced higher yields of cotton than calcium arsenate, lead arsenate, or cryolite in experiments for the control of the bollworm and the boll weevil and higher yields than sulfur or sulfur-arsenical mixtures in experiments for the control of the flea hopper. The increase in aphids following dusting with basic copper arsenate and sulfur was less than half as great as that following dusting with calcium arsenate or zinc-safened calcium arsenate. On cotton dusted with calcium arsenate there were 3.6 times as many aphids when 0.5 per cent of rotenone was added as when 1 per cent of nicotine was added. Calcium arsenate containing zinc sulfate did not show much promise in holding down aphids.—5-12-42.

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CORN BORER—CORN HYBRID LABORATORY

To facilitate the development of corn resistant hybrids adapted to the corn belt regions of the North Central States, the federal Bureau of Entomology and Plant Quarantine has established a laboratory at the Purdue University Agricultural Experiment Station, Lafayette, Indiana, where office facilities have been provided. The office will work in cooperation with the entomologists and plant breeders of all the North Central States where the corn borer problem is now acute or where it may become an important factor in corn production.

A. M. Vance, of the Toledo Corn Borer Laboratory, is in charge. Other entomologists transferred to this new station include R. T. Everly, L. H. Patch, and M. Schlosberg of the Toledo laboratory; L. L. Stitt from the federal laboratory at Tempe, Arizona, and E. J. Udine of the federal laboratory at Carlisle, Pennsylvania. A plant breeder will be added to the staff of the laboratory in the near future.

Control of Hemipterous Cotton Insects by the Use of Dusts[1]

J. R. Eyer and J. T. Medler,[2] *New Mexico Agricultural Experiment Station, State College*

Increasing damage to cotton by various species of Hemiptera has been observed over a period of several years in the irrigated valleys of southern New Mexico. These injuries consisted of the shedding of young squares and forms, distortion of the developing bolls, and spotting and staining of the lint. Surveys, which were conducted in the lower Rio Grande and Pecos Valleys in 1940 and 1941 and recorded in the 51st and 52nd Annual Reports of the New Mexico Agricultural Experiment Station, indicated that both numphs and adults of the following species were consistently present throughout the growing season: the "conchuela," *Chlorochroa ligata* (Say), the Say stinkbug, *C. sayi* Stål, the red shouldered stinkbug, *Thyanta custator* (Fabr.), the brown cotton bug, *Euschistus impictiventris* Stål, the tarnished plant bug, *Lygus oblineatus* (Say), the legume bug, *L. hesperus* Knight, the pale legume bug, *L. elisus* Van D., the superb plant bug, *Adelphocoris superbus* (Uhler), the cotton flea hopper, *Psallus seriatus* (Reut.), and the black cotton flea hopper, *Chlamydatus associatus* Uhler.

Observations in 1940 of these species confined in cages over cotton plants indicated that the shedding of squares was produced especially by the nymphs of *Lygus* spp. and that distortion of boll coverings and staining of lint attended the feeding of the same and also by the Say stinkbug and the superb plant bug.

In order to determine whether various grades of dusting sulphur and combinations of dusting sulphur with other insecticides, particularly arsenicals, would control these Hemiptera with a resulting improvement of yield, a randomized block experiment was conducted at State College in 1941. Observations of the toxicity of the sulphur-arsenical combinations to some of the above-mentioned species in cages were also included.

Plots and Treatment.—A field of Acala cotton, strain No. 2815, approximately 5 acres in area, was divided into 104 plots, each plot consisting of 4 rows 50 feet long. A single row at each side and a 10-foot space at each end were left between the plots for buffer areas. Twelve insecticidal treatments, which are listed in table 2, were replicated at random 8 times.

Table 1.—Dusting schedule and rainfall at State College, 1941.

Dates of Treatments	Precipitation (inches)	
June 3—First preventive treatment		
	June 15	.02
June 16—Second preventive treatment		
June 23—First regulr and third preventive treatment	June 23	.03
	June 26	.85
June 27—Fourth preventive treatment		
July 2—Second regular and fifth preventive treatment		
	July 3	.04
	July 6	.18
July 7—Sixth preventive treatment		
	July 11	.01
	July 12	.20
	July 14	.86
July 15—Third regular treatment and seventh preventive treatment		
	July 20	.79
July 25—Eighth preventive treatment		
	July 27	.02
	July 30	.02
	August 1	.23
	August 8	.03
August 12—Ninth preventive treatment		
	August 13	1.53
	August 19	.05
August 21—Tenth preventive treatment		
	August 22	.15
	August 24	.24

The entire area of each plot was dusted, but yield records of seed cotton were taken only from the two center rows. Consequently, the total area for the yield record of each treatment constituted about one-sixteenth acre.

Three applications of all of the treatments were made between June 23 and July 15, at intervals approximately a week apart. In addition, the combination of paris green and unconditioned sulphur, and unconditioned sulphur alone, were applied a sufficient number of times to maintain a continuous covereage of the plants

[1] Cooperative project of the New Mexico Agricultural Experiment Station and the Texas Gulf Sulphur Company.
[2] Research fellow, Texas Gulf Sulphur Company.

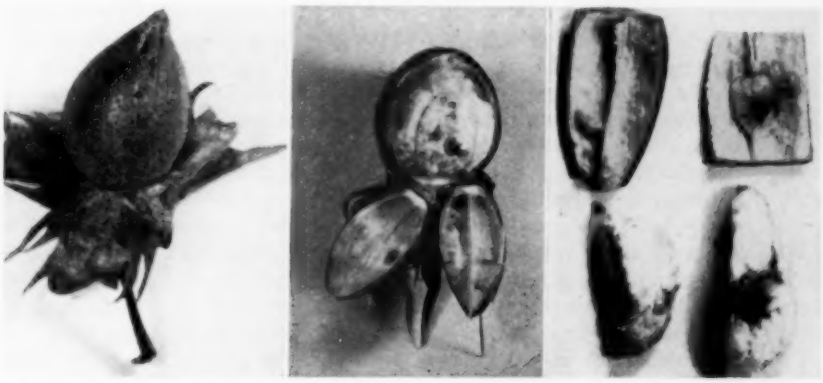

FIG. 1.—Types of injury produced on cotton bolls by hemipterous species. Left—Surface view of punctures of *Lygus hesperus*. Center—Boll with two valves removed to show staining on lint and inner wall of pericarp. Right, above—Inner surface of pericarp showing callus; below: Two locules removed to show staining of lint.

throughout the season, being renewed as soon as possible after each rain. The two treatments last mentioned are referred to as "preventive" to distinguish them from the regular series. A total of 10 preventive applications was made but four of these were washed off by heavy showers soon after their application. Therefore, only six were considered as remaining sufficiently long on the plants to be effective. Several times these dusts were removed by rain within 24 hours, as can be seen in table 1, which presents the dates of application in conjunction with the precipita-

Table 2.—Yield of seed cotton, State College, 1941.

TREATMENT	TOTAL PLOT YIELD (LBS.) (8 REPLICATES)	ESTIMATED YIELD PER ACRE, LBS.	INCREASE OVER UNTREATED CHECK, LBS.
1. Conditioned dusting sulphur 97–98% S, 93–95%—325 mesh	164.6	2,561	22
2. Conditioned dusting sulphur 97–98% S, 98–100%—325 mesh	163.6	2,546	7
3. Conditioned dusting sulphur 92–93% S, 98–100%—325 mesh	163.4	2,543	4
4. Black dusting sulphur 99% S, 98–100% —325 mesh, plus 1% carbon black	156.8	2,440	
5. Conditioned dusting sulphur 97–98% S, 93–95%—325 mesh, plus blood albumen (93–7)	163.2	2,539	
6. Resin dusting sulphur 70% S, 98–100% —325 mesh, processed with resin	166.4	2,589	50
7. Unconditioned dusting sulphur 99% S, 98–100%—325 mesh. Preventive treatment	161.0	2,505	
8. Unconditioned dusting sulphur 99% S, 98–100%—325 mesh, plus paris green (92.5–7.5). Preventive treatment	179.0	2,785	246
9. Unconditioned dusting sulphur 99% S, 98–100%—325 mesh, plus paris green (92.5–7.5)	169.2	2,633	
10. Unconditioned dusting sulphur 99% S, 98–100%—325 mesh, plus calcium arsenate (66.6–33.3)	165.6	2,577	37
11. Black dusting sulphur 99% S, 98–100% —325 mesh, plus 1% carbon black plus calcium arsenate (66.6–33.3)	165.0	2,567	28
12. Unconditioned dusting sulphur 99% S, 98–100%—325 mesh, plus powdered soap (95–5)	160.0	2,490	
13. No treatment	163.2	2,539	

tion records from a standard rain gauge located at the college weather station about one-eighth mile from the experimental field. Of the regular series, only the last application remained undisturbed by rain for 5 days.

Early in the season, when the plants were small, the dusts were applied with a single-nozzle rotary fan type hand duster at the rate of approximately 15 pounds to the acre. Later, when the plants were larger, a traction wheelbarrow duster with two nozzles per row was used and between 20 and 25 pounds to the acre was applied. The applications were made early in the morning when there was no wind, to prevent, as much as possible, the drifting of dusts from one plot to another.

RECORDS.—The following methods were used in evaluating the effect of the field applications of the insecticides: (1) a determination of the percentage of bolls showing types of injury characteristic of the species concerned, *i.e.*, simple puncturing of the boll covering, formation of callosities on the inner wall at the site of punctures, and staining of the lint and the inner portion of the boll (Fig. 1); (2) determination of the average number of bolls per plant and the percentage of bolls free from injury just before picking; and (3) a record of the amount of seed cotton harvested from the two middle rows of the 8 replications of the 12 treatments. Since the general results obtained by all three methods were in agreement, the yield records will be discussed first.

RESULTS.—Table 1 presents the total and mean plot yield, estimated yield per acre, and the estimated acre increase of each treatment over the untreated check. The highest yield was obtained from the preventive treatment of paris green and unconditioned sulphur, *i.e.*, 179 pounds of seed cotton from the 8 replications or an estimated yield of 2785.24 pounds per acre. The estimated increase of this plot over the untreated check was 245.85 pounds per acre. Three applications of the same insecticidal combination gave the next highest yield, *i.e.*, 169.2 pounds or an estimated 2632.75 pounds per acre. maller gains were obtained from the combinations of calcium arsenate and dusting sulphurs and from an experimental combination of dusting sulphur and resin. The remaining treatments showed little or no gain over the untreated check. Student's method for analysis of small samples was used to test the significance of the highest yielding plots in comparison with the untreated check. In the preventive application of paris green and unconditioned sulphur the difference between mean yield satisfied the figure needed for significance, (1.76) at the 1-per cent level and ap-

Table 3.—Average number of bolls per plant, percentage uninjured bolls and percentage injury types, State College, N. Mex., 1941, from cotton treated with various combinations with dusting sulphur.

Treatment	Total Bolls Examined on 40 Plants	Per Cent Uninjured	Percent Injury by Types		
			Simple Puncture	Puncture + Callus	Punctures, Callus and Staining
1. Conditioned sulphur 93–95/325	456	92.5	30	0	0
2. Conditioned sulphur 98–100/325	508	85.0	20	40	10
3. Conditioned sulphur 98–100/325 93% S	486	92.5	30	0	0
4. Black sulphur	459	85.0	10	20	30
5. Conditioned sulphur and blood albumen	471	85.0	0	10	30
6. Resin sulphur	515	87.5	30	40	20
7. Unconditioned sulphur. Preventive treatment	464	90.0	0	30	10
8. Unconditioned sulphur plus paris green. Preventive treatment	561	97.5	0	10	0
9. Unconditioned sulphur plus paris green	526	95.0	10	10	0
10. Unconditioned sulphur plus calcium arsenate	482	95.0	10	10	0
11. Black sulphur plus calcium arsenate	515	90.0	20	0	10
12. Unconditioned sulphur plus powdered soap	437	80.0	10	60	10
13. No treatment	449	80.0	20	0	20

proached that needed at the 5-per cent level (2.15). The fact that heavy rains removed one of the regular applications and four of the preventive treatments almost immediately after their application may be considered as a possible reason why none of the other differences between treatments was sufficiently large to show significance.

Table 3 presents the data gathered by determining the average number of mature bolls per plant, the percentage of injury-free bolls and the percentage of the types of boll injury observed. The number of bolls per plant and the percentage of injury-free bolls were highest in the samples taken from the preventive treatment of paris green with sulphur and the occurrence of the three common types of boll injury was least in this series. The plots dusted with three applications of paris green and sulphur and with calcium arsenate and unconditioned sulphur also ranked high in these same respects.

CAGE TESTS.—Comparisons were made in field cages of the toxicity of unconditioned dusting sulphur and the same in combinations with paris green and calcium arsenate. All species mentioned in the introductory paragraph were used but only three could be collected in sufficient numbers to be subjected to a large number of comparisons, *i.e.*, *Chlorochroa sayi*, *Lygus hesperus*, and *Adelphocoris superbus*. The type of cage used consisted of a light wooden frame 48 inches high and 30 inches square, covered on three sides with 16-mesh window screen and on the top and remaining side with muslin sheeting. Each cage was fitted into a wooden base over a painted wallboard floor which was fitted around the base of the plant, all cracks being sealed with scotch tape to prevent escape of insects. The adults of each species were collected from cotton, alfalfa, and sugar-beet fields by sweeping or were picked from alfalfa or sugar beet plants as these were harvested for forage and seed. The number of adults used for each test was dependent on their abundance and availability at the time the comparisons were being conducted. Each species was placed in cages for 24 hours preceding any application of insecticides

Table 4.—Effectiveness of combinations of arsenicals and sulphur against cotton feeding Hemiptera in cages, State College, N. Mex., 1941.

Insecticides	*Chlorochroa sayi*			*Lygus hesperus*			*Adelphocoris superbus*		
	No. of Tests	No. Insects	Per Cent Mortality[1] in 4 Days	No. of Tests	No. Insects	Per Cent Mortality in 4 Days	No. of Tests	No. Insects	Per Cent Mortality in 4 Days
Calcium arsenate (Dow) unconditioned sulphur, 33–66%	3	106	52.8	1	10	63.0	1	10	75.0
Calcium arsenate (High test)[2] and unconditioned sulphur, 33–66%	2	78	41.2	1	25	30.4			
Calcium arsenate (Dow) and black sulphur, 33–66%	3	102	63.9	1	25	56.5			
Calcium arsenate (High test) and black sulphur, 33–66%	2	75	36.1	1	25	30.4			
Unconditioned sulphur	1	25	8.6	1	10	13.7	1	10	2.9
Paris green (Dow) and unconditioned sulphur, 7–93%	1	50	8.3	1	10	22.2	1	10	62.5
Paris green (air floating) and unconditioned sulphur, 7–93%	2	75	19.7	1	25[3]	48.0			
Paris green (air floating) and black sulphur, 7–93%	2	75	15.3	1	25[4]	44.0			

[1] Corrected against the untreated series using "Abbott's formula."
[2] No. 584 of the Niagara Sprayer and Chemical Company. Analysis: 4.3% soluble arsenic.
[3] 11 adults escaped.
[4] 14 adults escaped.

and only those groups which showed less than 2 per cent natural mortality during this period were used. The insecticides were applied by thoroughly dusting the caged plant and the inside of the cage with a plunger-type hand duster, operated through the large sleeve-type opening of the muslin wall. The plant in the cage was thoroughly covered but no special effort was made to subject the insects to a heavier application than would result from ordinary field application with the same type of apparatus. Examinations were made each 24 hours for 4 days and the mortalities resulting at the end of that time are recorded in table 4. From this table it may be seen that both paris green and calcium arsenate in combination with dusting sulphur at the same strengths as used in the field tests consistently produced mortalities of the Say stinkbug and the superb plant bug well above that of sulphur alone or of the natural mortality. In the case of *Lygus*, these mortalities were variable and inconsistent which may be attributed in part to the fact that this species was restless in cages and evidenced a rather high natural mortality.

SUMMARY.—Hemiptera of the families Pentatomidae and Miridae injure cotton in the irrigated valleys of southern New Mexico. The most important are *Adelphocoris superbus* and species of the genera *Lygus* and *Chlorochroa*. In order to determine the efficacy of various insecticidal dusts for their control, a randomized block experiment was conducted at State College in 1941. It was found that substantial increases in yield of seed cotton were obtained with dusts of paris green and sulphur and calcium arsenate and sulphur. These arsenical-sulphur combinations also produced relatively high mortalities in the case of three species (*i.e.*, *C. sayi*, *L. hesperus* and *A. superbus*), confined in large field cages.—6-14-42.

Control of Flea Beetles on Cigar-Wrapper Tobacco with Cube Dust in the Florida-Georgia Area

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The tobacco flea beetle, *Epitrix parvula* F., is a major insect pest of shade-grown cigar-wrapper tobacco in the Florida-Georgia producing area (Chamberlin & Tenhet 1923). The injury consists of small, irregular holes in the leaves produced by the feeding of the adults. The presence of these holes decreases the number of cigar wrappers that can be produced from the leaves. Leaves moderately punctured may be reduced in value, from a small amount to 50 per cent, depending upon the number and the position of the holes. Injury is sometimes so severe that no wrappers can be obtained, and the tobacco is thus reduced to the filler grade with a very heavy loss in value.

Whereas experiments and commercial practice have indicated that flea beetles may be controlled successfully upon cigar-wrapper tobacco in this area by the applications of cube or derris dusts containing 1 per cent of rotenone (Chamberlin & Madden 1937), the problem of timing remained to be solved. Therefore, field experiments were conducted at Quincy, Fla., during the period 1938 to 40 to determine, as far as possible, the proper timing of the dust application and the total number needed for control.

EXPERIMENTAL METHODS.—The experimental tobacco was grown under shade conditions, in accordance with commercial practice, and the field was divided into 16 plots, 69 by 50 feet, arranged in a latin square. Each of 4 dusting schedules was replicated on 4 plots. Barriers of shade cloth the same height as the shade structure were erected between each block of plots after the overwintered beetles had entered the field and had had an opportunity to spread over the plots. The purpose of these barriers was to prevent dust drift and retard further flea beetle movement. A single shaded plot

[1] Acknowledgments are due L. L. May for field assistance and the staff of the North Florida State Experiment Station for aid n this cooperative project.

about the size of the dusted plots served as an unpoisoned check. It was separated from the dusted area by a 14-foot roadway and by a triple shadecloth wall the height of the shade structure. Whereas the data obtained from the check plot have no statistical value, they are included for the purpose of indicating general comparisons between dusted and undusted tobacco.

A mixture of powdered cube root and powdered sterilized tobacco in such proportion as to make a rotenone content of 1 per cent was applied in all dusting schedules. Dust mixtures made from ground derris root appear to be as effective against the tobacco flea beetle as mixtures made from cube root, but cube was used exclusively in these experiments. During the early part of the growing season, a dosage of 4 pounds per acre was used when the plants were about 2 feet in height, but when the plants became larger the dosage was increased to 6 pounds. All applications were made with rotary hand dusters. The majority of the treatments were made about 7 a.m., when there was usually little air movement. Four dusting schedules were tested each season, as follows: (1) Two applications each week, (2) one application each week, (3) one application every 10 days, and (4) one application every 2 weeks. The beetle infestation varied greatly from one year to another, and the total number of applications made in a season depended on the severity of the infestation.

The results of the experiments were evaluated from the percentages of leaves injured by the beetle and from the amount of damage caused by the insect. The term "injury" as used in this paper refers to any visible defect caused by the feeding of the insects, whereas "damage" refers to injury that materially affects the market value of the product. The leaves used for the treatment evaluations were harvested from 60 plants located near the center of each plot and cured in the usual commercial fashion. After curing, each leaf was placed on a large groundglass plate, which was illuminated from beneath, so that the smallest injury could be detected. Records were made of the percentages of leaves injured and damaged and the estimated reduction in value of the damaged leaves. Leaf damage and reduction in value were determined in accordance with a system used locally for grading cigar-wrapper tobacco. By this system the tobacco is graded on the basis of the size and location of holes that affect the cutting of sound wrappers from the leaves. Although various sizes and shapes of wrappers are used in cigar manufacture, the wrapper commonly used in the machine production of cigars consists of a strip of tobacco leaf about 2 inches wide and 10 inches long. In practice it is assumed that each leaf has a potential yield of at least four sound wrappers, two being cut from each half of the leaf area separated by the midvein (Morrill 1941). Injuries near the midvein, or so placed that they do not cause the loss of wrappers, are disregarded. For experimental purposes the following grades were used: No. 1, Leaves free of damage; No. 2, damaged leaves with not more than one-fourth of the area damaged and unfit for wrappers; No. 3, leaves damaged to a greater extent than in grade 2, but with not more than three-fourths of their area unfit for wrappers; and No. 4, leaves damaged to a greater extent than in grade 3. Information obtained from tobacco trade representatives indicated that leaves included in grades 1, 2, 3, and 4 sustain an average reduction in value of approximately 0, 36, 51, and 92 per cent, respectively. The numbers of leaves in each of the four grades and the percentages of reduction in value for each were used to calculate the reduction in total crop value. It should be noted that these percentages are relative and should therefore remain constant regardless of changes in tobacco prices.

An attempt was made to evaluate the results of the experiments by means of a series of beetle-population counts, but these records appeared to be of doubtful value, owing to the difficulty in obtaining counts in the dense foliage of shade-grown tobacco, and were therefore not included.

RESULTS OF 1938.—In 1938 the flea beetle infestation was relatively heavy. Whereas in the dusted plots only about one-third of the newly set plants showed evidences of the overwintered beetles, in the undusted check plot there were about 14 beetles per stalk near the end of the harvesting season.

The dust applications were begun the day after the crop was transplanted and were continued for 11 weeks, or until the

foliage growth had become so heavy that dusting could be performed only with considerable breakage of the leaves.

The results of the 1938 experiment are shown in table 1. These data indicate that the control obtained from weekly applications was very nearly the same as that from semiweekly applications. The estimated reduction in value of the tobacco dusted according to these schedules (less than 2 per cent) would not usually be considered of commercial importance.

Whereas this experiment was designed to indicate the probable number of applications needed to control the beetle, the writers are of the opinion that the relatively small area included in the experiment had a somewhat heavier initial infestation than the larger commercial fields and for this reason required somewhat greater quantities of the insecticide.

RESULTS OF 1939.—Overwintered flea beetles were less abundant on the newly set plants in the 1939 experiment than in the experiment of the previous year. Unusually heavy rains, which occurred at frequent intervals during the tobacco-growing season, were evidently unfavorable for the propagation of the insect, and the later generations were present in only moderate abundance. The undusted check plot, being located on somewhat lower ground than the dusted plots, was partially flooded several times and was, therefore, relatively unfavorable for flea beetles.

The first application in all schedules was made the fourth day after the crop was transplanted, and dusting was continued for 7 weeks.

Table 1.—Damage to cigar-wrapper tobacco by the tobacco flea beetle as influenced by the frequency of application of cube dust mixture containing 1 per cent of rotenone.

FREQUENCY OF DUST APPLICATIONS	TOTAL APPLICATIONS	LEAVES EXAMINED	LEAVES INJURED	LEAVES DAMAGED	ESTIMATED REDUCTION IN VALUE
	Number	*Number*	*Per Cent*	*Per Cent*	*Per Cent*
			1938		
Semiweekly	21	3,303	14.4	4.4	1.6
Weekly	11	3,322	16.5	4.7	1.7
Every 10 days	7	3,265	31.0	12.0	4.7
Biweekly	5	3,279	37.3	14.5	5.9
Check[1]	0	1,038	99.4	95.1	72.0
Differences required for minimum significance	—	—	11.4	5.2	—
			1939		
Semiweekly	14	2,576	3.8	1.3	0.5
Weekly	7	2,520	10.4	3.4	1.3
Every 10 days	5	2,649	15.0	6.0	2.2
Biweekly	4	2,659	20.3	9.1	3.4
Check[1]	0	626	58.1	35.6	14.3
Differences required for minimum significance	—	—		—	—
			1940[2]		
Semiweekly	7	2,630	8.4	1.5	0.6
Weekly	4	2,616	13.2	3.9	1.4
Every 10 days	3	2,528	16.8	5.1	1.9
Biweekly	2	2,371	30.6	11.1	4.2
Check[1]	0	611	79.4	42.5	17.5
Differences required for minimum significance	—	—	8.6	5.0	—

[1] The check was not randomized in respect to the other treatments, and therefore the results were not included in the analysis.
[2] The difference required for significance was not computed, as the F test showed that the observed differences were not significant.

At the prevailing price of cube dust and labor an application can be made at a cost of about 78 cents per acre. With an average crop value of about $700 per acre for the period 1938 to 40, a cost of $8.58 for 11 applications is easily justified. The leaf damage in plots dusted every 10 days and every 2 weeks was appreciably greater than that in the other treated plots and would be of commercial importance. The monetary reduction on these plots, due to the feeding of flea beetles, is estimated at $32.90 and $41.30 per acre, respectively. A weekly schedule of applications, 11 applications for the season, gave the most economical control.

The results obtained in 1939 are given in table 1. These data show that flea beetle injury was relatively light in all dusted plots but moderately severe in the check plot. Weekly and semiweekly applications gave sufficient control, as indicated by the data. Damage in the plots receiving one application every 10 days and a total of five dustings reached a critical point, but it would not usually be considered of commercial importance. This schedule gave the most economical control.

From a practical viewpoint it is not usually considered expedient to limit the number of applications to those necessary to prevent damage. In the dense growth of a field of shade-grown tobacco it is impossible for the grower to keep an accurate check of the abundance of flea beetles or of the damage they are inflicting on the crop, and experience has shown that comparatively few beetles frequently cause considerable damage before the grower is aware of their presence. For these reasons it is inadvisable to limit the number of the applications too closely.

RESULTS OF 1940.—In 1940 infestations of the flea beetle were unusually light throughout the northern Florida tobacco-producing region. The same conditions existed in the experimental field. The crop was transplanted in this field on April 5, and the plants were temporarily stunted by a freeze which occurred on the 13th. For the following several weeks cold weather prevailed, the plants made slow growth, and few beetles were present. During the last week in May the infestation increased, and the first application was made. Owing to the light infestation, the schedule was limited to 4 weeks.

The results in 1940 (table 1) show that 7, 4, and 3 applications each gave satisfactory commercial control. The damage on the plots receiving only two applications, however, represents an estimated monetary loss of $29.40 per acre. A total of three applications, spaced 10 days apart, gave the most profitable control.

SUMMARY AND CONCLUSIONS.—Experiments were conducted at Quincy, Fla., during the period 1938 to 40 for the purpose of determining the proper schedule and number of applications of a cube root and tobacco dust mixture containing 1 per cent of rotenone for the control of the tobacco flea beetle on cigar-wrapper tobacco. Applications were made semiweekly, weekly, every 10 days, and biweekly. Each schedule was replicated 4 times in a 16-plot latin square, and a single untreated plot served as a check. The total number of applications in each schedule varied each season depending on the severity of the infestation. Records were made of the leaves injured and damaged and the reduction in value of cured leaves.

The results indicate that the most profitable schedule may be expected to vary from season to season. One application per week, with a total of 11 applications for the season, gave the most economical control under conditions of heavy infestation while 1 application every 10 days, with a total of 3 applications per season, was sufficient with a very light infestation.

Owing to the low cost of the control compared with the value of the crop and to the difficulty of determining the extent of the infestation under field conditions, it seems undesirable to limit the number of applications to the minimum that appears to be necessary for the prevention of damage. It seems that 1 application per week from transplanting time until the crop approaches maturity will normally give adequate protection—6-22-42.

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Development and Use of Sugarcane Varieties Resistant to the Sugarcane Borer

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It has been known for many years that there are differences in degree of susceptibility among varieties of plants to plant diseases and insect pests. This knowledge has been successfully utilized in combating plant diseases. Sugarcane mosaic has been efficiently controlled by growing resistant varieties of sugarcane. The use of resistant plant varieties to combat insect pests is a relatively new field of study, but one in which there have been many recent and encouraging developments. A recent survey of the literature on the subject (Snelling 1941) shows that records of resistance have been reported on nearly 100 plant species, and over 100 insect species are involved. A few outstanding examples are the resistance of Asiatic cottons to the pink bollworm, Northern Spy apple to the woolly apple aphid, Kieffer pears to the San Jose scale, American grapevines to the grape phylloxera, and of certain varieties of wheat, alfalfa, and sorghums to the hessian fly, pea aphid, and chinch bug, respectively. Where successful, the planting of resistant varieties has many advantages over most other methods of insect control in that it costs the grower nothing additional in the way of money, labor, or cultural practices and is economically practical to use, where the insect infestation is light, on marginal lands and with crops of low money value. It is also one of the most stable forms of pest control, as it reduces to a minimum the fluctuation of insect injury from one year to the next.

Investigations of the resistance of different varieties of sugarcane to the sugarcane borer were begun in 1933 and continued through to the present by the Bureau of Entomology and Plant Quarantine, of the United States Department of Agriculture, in cooperation with the Bureau of Plant Industry, of that Department. The present discussion does not attempt to answer conclusively the more important questions of resistance in sugarcane, as many phases of the study have just been initiated and others have not been completed. The general objectives of the investigations are (1) to determine the relative resistance of the more common commercial varieties of sugarcane to the sugarcane borer, (2) to determine the desirability, from the standpoint of borer resistance, of releasing new varieties and what advice may be given sugarcane growers on the amount of borer damage to be expected for the varieties, and (3) to discover and breed new sugarcane varieties resistant to the borer.

RESISTANCE OF COMMON VARIETIES OF SUGARCANE TO THE BORER.—The relative amount of borer injury to the more common commercial varieties of sugarcane has been studied over a period of several years. Infestation counts were made in replicated test fields of the Bureau of Plant Industry in both plant and stubble cane on each of 3 representative plantations during each year of the period 1936–41. To obtain a good comparison of borer injury, the examinations were made in fields located in light soil areas, where borer infestation is usually heavy. All final infestation records were taken while the fields were being harvested. These records were obtained annually by determining the percentages of joints showing borer injury externally for approximately 100 stalks of each variety in each field. Usually 20 stalks were examined in each of five replicated plots.

A summary of borer injury to both plant and first-stubble cane of eight varieties grown on each of three plantations during the past 6 years is given in table 1. A comparison of joints bored in both plant and stubble cane shows that variety Co. 290 had the least amount of injury, or 73 per cent as much as had Co. 281. Varieties C. P. 29/103, with 35 per cent more infestation than Co. 281, and C. P. 29/116, with 19 per cent more infestation than Co. 281, had the greatest amount of borer injury. There was little difference between varieties C. P. 29/320, C. P. 28/11, C. P. 28/19, and C. P. 29/120, as all had, in descending order, from 95 to 82 per cent of the infestation of Co. 281.

Table 1 shows plant cane to have a

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higher infestation than first-stubble cane for each of the eight varieties. Much of this difference is probably due to plant cane being harvested much later than first-stubble cane and thus being subjected to a heavy infestation over a longer period. The infestations should be more equal when both crops are harvested at the same time.

During the years 1939, 1940, and 1941 counts were made of the dead hearts caused by first-generation borers in replicated test plots of stubble cane in four locations. A total of approximately 12,000 row-feet of each cane variety was examined. When early borer injury was compared with harvest time injury there was found to be a strong positive relationship between the two. Although extensive field examinations in replicated plots during a period of 4 years have given some evidence that the most severely bored varieties receive the most eggs and largest egg masses, these data have not been sufficiently consistent to be conclusive.

Information gained from varietal-resistance studies suggests that, to decrease borer damage, Co. 290 should be planted in areas which normally have a heavy infestation, if such areas are agronomically satisfactory. The variety Co. 290 has proved to be the least subject to infestation and in addition suffers very little loss in sucrose from the borer injury that does occur. With 20 per cent of the joints bored, other varieties have lost about 10 per cent in sucrose. C. P. 29/103 and C. P. 29/116 are extremely susceptible to the borer and if planted in areas of heavy infestation are not only apt to be severely injured, but in addition may furnish an increased number of moths, which will raise the infestation of adjoining fields. There is much evidence that given the same number of borers at the beginning of the season the number by harvest time will be much greater on susceptible varieties than on resistant varieties. This can be accounted for by the higher rate of larval survival in susceptible varieties, by the more rapid rate of borer development, and by the production of possibly larger moths capable of laying more eggs. Data obtained thus far in nutritional studies,

Table 1.—Percentage of joints bored in eight common commercial varieties of sugarcane grown in Louisiana during the years 1936–41.

Year	Variety							
	C. P. 28/11	C. P. 29/116	C. P. 29/320	C. P. 28/19	Co. 281	Co. 290	C. P. 29/103	C. P. 29/120
				Plant Cane				
1936	29.77	32.98	23.71	25.44	23.53	15.40	32.40	23.89
1937	28.78	35.84	34.77	32.44	33.82	23.23	—	38.19
1938	30.35	43.99	40.56	31.33	40.87	26.79	—	—
1939	31.14	40.85	32.42	25.71	33.40	26.78	—	—
1940	—	—	13.49	15.13	13.47	7.74	22.34	15.57
1941	—	38.41	28.23	26.67	33.79	26.11	36.71	28.05
Actual average	—	—	28.86	26.12	29.81	21.01	—	—
Weighted average[1]	91.00	116.00	97.00	88.00	100.00	70.00	129.00	101.00
				First-Stubble Cane				
1936	13.03	16.36	14.68	14.11	15.51	9.80	19.66	—
1937	21.02	29.18	19.74	18.90	24.73	14.91	36.60	17.87
1938	26.60	40.58	30.89	24.18	32.21	20.94	—	15.74
1939	25.43	37.46	28.89	22.50	29.87	26.36	—	—
1940	15.46	15.16	9.03	9.01	10.94	6.01	—	—
1941	—	—	22.60	18.66	23.91	22.25	34.24	16.16
Actual average	—	—	20.97	17.89	22.86	16.71	—	—
Weighted average[1]	90.00	122.00	92.00	78.00	100.00	73.00	141.00	62.00
				Average of Plant and First-Stubble Cane				
Actual average	—	—	24.92	22.01	26.34	18.86	—	—
Weighted average[1]	90.00	119.00	94.00	83.00	100.00	72.00	135.00	82.00

[1] Weighted average (Co. 281 equals 100) is obtained by dividing the percentage of joints bored for a particular variety by the percentage of joints bored for variety Co. 281 growing in the same replicated tests for the same year or years.

using susceptible and resistant varieties, have shown the rate of borer development and survival to be higher in susceptible varieties.

Present-day commercial varieties are less susceptible to the borer than those grown formerly. Louisiana Purple, D-74, D-95, P. O. J. 213, and P. O. J. 234 were severely injured by the borer, and because of this susceptibility they tended to increase the borer population over the entire cane-growing area. P. O. J. 36 and P. O. J. 36M had medium to light infestations. Injury to C. P. 807 was comparatively light.

COMPARATIVE SUSCEPTIBILITY TO BORER INJURY OF SEVERAL PROMISING NEW VARIETIES OF SUGARCANE POTENTIALLY SUITABLE FOR RELEASE TO GROWERS.—Most of the more promising varieties not yet released for commercial production and their relative resistance to injury by the sugarcane borer are given in table 2. The years tested, number of samples examined, number of stalks examined, and the relative percentage of joints bored, based on control variety Co. 281 equaling 100, are given for each of the 38 varieties listed. The infestation figures for the 13 varieties marked with an asterisk are considered reasonably reliable because of the consistent performance of the samples tested and the large number of stalks examined. Two of these 13 varieties, C. P. 33/409 and C. P. 34/79, have been found to be decidedly resistant to the borer. The first had only 43 per cent as much infestation as variety Co. 281 and the second had only 54 per cent. Both these varieties grow well in light soils, which usually have the heaviest infestations. If either of these varieties, preferably C. P. 33/409, should be released for commercial culture by the three agencies, the Louisiana State Agricultural Experiment Station, the Bureau of Plant Industry, and the American Sugar Cane League, which cooperate in agronomic tests of new varieties and mutually decide whether varieties are suitable for release for commercial culture, they should prove to be a major contributing factor for control of the sugarcane borer. Not only should they have about half the infestation of the average present-day commercial varieties, but, because of their reduction of the borer population, the overflow to adjoining fields of more susceptible varieties should be less.

NEW VARIETIES RESISTANT TO THE BORER.—The purpose of these investigations is (1) to determine what sugarcane varieties are resistant to the borer, (2) to intensify and transfer resistance to agronomically desirable varieties, and (3) to determine what plant characters are associated with resistance as an aid in breeding borer-resistant varieties of sugarcane. The breeding and agronomic studies are conducted by the Bureau of Plant Industry, the entomological investigations by the Bureau of Entomology and Plant Quarantine, and the work on resistance to the sugarcane borer cooperatively by the two agencies.

Approximately 7000 varieties of sugarcane grown in the seedling nurseries of the Bureau of Plant Industry have been examined during the past 3 years in an effort to find new varieties resistant to the sugarcane borer. Incidentally, all selec-

Table 2.—Comparative susceptibility to sugarcane borer of several promising new varieties of sugarcane potentially suitable for release to growers, as determined from percentages of joints bored.

VARIETY	YEARS TESTED	SAMPLES EXAMINED	STALKS EXAMINED	SUSCEPTIBILITY RATING (CO. 281 = 100)
C. P. 29/99*	1938–39	23	305	128
C. P. 29/137*	1938–39–40–41	65	1,144	116
C. P. 31/509*	1938–39–40–41	84	1,484	85
C. P. 31/529	1940–41	12	238	92
C. P. 32/202*	1938–39–40	56	935	76
C. P. 32/206*	1939–40–41	45	872	78
C. P. 32/134	1939–40	18	330	93
C. P. 32/324*	1939–40–41	27	540	128
C. P. 33/224*	1939–40–41	27	506	132
C. P. 33/233*	1940–41	11	210	189
C. P. 33/243*	1939–40–41	45	864	120
C. P. 33/253*	1939–40–41	36	691	73
C. P. 33/372*	1940–41	30	579	70
C. P. 33/409*	1939–40–41	32	590	43
C. P. 33/485	1940–41	6	90	65
C. P. 34/1	1940–41	12	226	104
C. P. 34/21	1939–40–41	13	273	68
C. P. 34/53	1940–41	6	88	75
C. P. 34/54	1940–41	6	89	47
C. P. 34/75	1940–41	6	90	68
C. P. 34/77	1940–41	12	223	66
C. P. 34/79*	1940–41	29	569	54
C. P. 34/86	1940–41	6	90	177
C. P. 34/92	1940–41	6	90	54
C. P. 34/115	1940–41	6	88	122
C. P. 34/120	1940–41	12	238	85
C. P. 34/139	1941	2	32	90
C. P. 34/141	1941	4	61	72
C. P. 34/143	1941	4	60	84
C. P. 36/17	1941	4	58	64
C. P. 36/19	1941	4	62	75
C. P. 36/55	1939–40–41	4	50	46
C. P. 36/62	1941	2	30	72
C. P. 36/70	1939–41	3	40	82
C. P. 36/75	1939–41	3	40	75
C. P. 36/85	1939–40–41	4	50	40
C. P. 36/94	1939–41	3	40	93
C. P. 36/105	1941	2	30	90

* Infestation figure is considered reasonably reliable because of the consistent performance of the samples tested and the total number of stalks examined.

tions made from the seedling nurseries are inspected for percentage of joints bored. By measuring this variable of infestation, workers are able to appraise more accurately the agronomic qualities of the seedlings selected. Varieties with the lowest average infestation are planted in replicated plots and artificially infested for purposes of more intensive study. Artificial infestations are made to insure uniformity of infestation from sample to sample and to provide a sufficient borer population to produce clear-cut varietal differences in reaction. It has been thought that differences in varietal infestations occurring when many varieties are planted close together in small plots may be due to selection by ovipositing moths rather than actual resistance in the more lightly infested varieties and that the results would be different under field conditions, because, in the absence of varieties attractive to the moths, eggs would be laid on unattractive varieties. A small bit of paper bearing 50 eggs of the sugarcane borer that are ready to hatch is pinned to each of the cane stalks in the test.

A total of 106 varieties have been tested by artificial infestation. Of this number, 10 have shown themselves to be definitely resistant. Four varieties that have maintained their resistant status throughout these tests have already been selected as parents to be used in crosses designed to increase the element of resistance and to transfer it to agronomically desirable varieties adapted to specific localities.

The comparative susceptibility of progeny of different sugarcane crosses to injury by the sugarcane borer has been studied during the past 5 years to determine the extent to which certain parents tend to produce borer-resistant progeny. The ultimate aim of these studies is to obtain information that may be of value in breeding resistant varieties of cane. A total of more than 3500 seedling varieties, in which 153 different parents were used, was examined for injury by the sugarcane borer. This work has shown that four of these parents, C. P. 1165, P. O. J. 2725, C. P. 28/9, and C. P. 27/108, are definitely susceptible; one parent, N. G. 251, is resistant, and three parents, Co. 281, U. S. 1694, and C. P. 28/100, are neutral. All the remaining parents are represented by only one-tenth the total number of seedlings examined, and additional field data on their reactions to the borer must be obtained before they can be conclusively placed in any injury group. The average borer infestation for the five crosses in which N. G. 251 was a parent was one-third less than that for control variety Co. 281. From a total of 110 examined seedlings resulting from crosses with this resistant parent 86 seedlings, or 78 per cent, were injured less by the borer than was control variety Co. 281.

Studies were made of several plant characters that might be associated with resistance to borer injury. In 1933 and 1934 a rind-puncturing instrument was used in the variety test fields of the Bureau of Plant Industry to determine hardness of rind characteristic of the different varieties. Readings were taken in pounds at the bottom, middle, top, and collar of the cane stalks. Readings were also taken on the leaves of a few plants but were found unsatisfactory and were discontinued. Very little difference between varieties was noted in hardness of rind near the top and collar. Results showed no definite relation between hardness of rind and percentage of joints bored. Varieties P. O. J. 213 and Co. 290 have rinds of approximately the same hardness, yet the former is one of the most susceptible varieties and the latter one of the most resistant. Variety C. P. 28/19 has a much harder rind but a higher percentage of joints bored than P. O. J. 36M. Just the opposite is true for variety P. O. J. 234, which has a softer rind and a higher percentage of joints bored than variety C. P. 807. No correlation has been found thus far between fiber content of the stalk or leaf spindle and degree of borer injury. The absence of a definite association between borer injury and either rind hardness or fiber content of the stalk may possibly be due to the small number of varieties examined.

In cooperation with the Bureau of Plant Industry a study was made at Houma, La., of the relative borer injury to sugarcane stalks at harvest time in 1934. This study included stalks of four ages for each of 10 varieties of plant cane. The original, or "mother," stalks were tagged on April 11, "first-order suckers" on April 20, and "second-order suckers" on May 29. "Third-order suckers" represent stalks which appeared after May 29. At harvest time in December the percentage of joints

bored in approximately 100 stalks of each order of each variety was determined. Mother stalks and first-order suckers had the least infestation in spite of the fact that they were subjected to borer injury over a longer period. The youngest stalks had the highest infestation. The same experiment, except for minor variations, was repeated in 1935, and the results were almost identical. Similar results were obtained from an experiment with stalks of different ages in 1938. These results indicate the advisability of planting varieties that produce a large number of early stalks.

In 1936 and 1937 a study was made of the relation between borer damage and diameter, height, and color of stalks, and width of leaves. A total of 1200 varieties in the seedling nurseries of the Bureau of Plant Industry were included in these studies. In 1939 the relation of the same plant characters and several others to borer infestation were also studied in 159 varieties from a single cross. These studies showed higher percentages of joints bored in varieties with large stalk diameters than in varieties with small stalk diameters. Nevertheless, varieties with the shortest stalks as well as those with the lightest stalks were most severely bored. Possibly the greater severity of the borer injury in these varieties was the cause rather than the result of the shortness and lightness of the stalks. Varieties with a high percentage of sucrose were less severely injured than those with a low percentage of sucrose. This may indicate that borer injury reduces the percentage of sucrose rather than that the percentage of sucrose affects the degree of borer damage. Varieties whose stalks had a relatively large amount of pith were more severely damaged than those with a small amount of pith. There was no relationship between borer injury and color of stalks, width of leaves, or ease of stripping.—5-11-42.

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Results Attained in the Biological Control of *Diatraea saccharalis* (F.) in Florida[1]

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Sugarcane is cultivated for the production of sugar in two distinct areas in southern Florida, one around Lake Okeechobee and the other at Fellsmere. According to Ingram, *et al.* (1939) 20,000 acres of sugarcane were planted in 1937 in this area, which produced 57,000 tons of raw sugar. In 1940 the area produced 101,000 tons of raw sugar from 29,900 acres of cane.

The sugarcane borer, *Diatraea saccharalis* (F.), is the most injurious insect attacking this crop in continental North America, Puerto Rico, Cuba, and probably the whole Western Hemisphere. In Florida the sugarcane borer exists in both areas mentioned, but, owing apparently to differing ecological conditions, its damage is more severe at Fellsmere than around Lake Okeechobee. The previously mentioned writers have reported that estimated percentages of stalks and joints bored, based on counts of joint infestation made at harvest time in January 1937, were as follows: Fellsmere, stalks 47.2 and joints 6.39; Lake Okeechobee, stalks 34.8 and joints 3.86.

To diminish this damage several attempts have been made to colonize some of the natural enemies of the sugarcane borer from Cuba, Puerto Rico, and South America for its biological control. Introductions into Florida began in 1926, when puparia of the tachinid fly *Lixophaga diatraeae* (Towns.), also known as the Cuban fly, were sent by Plank (Jaynes 1938b) for colonization at the experiment stations at

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Canal Point, Bradenton, and Lake Alfred, but there is no record of any recovery from the releases of this material.

In 1932 several thousand specimens of the braconid wasp *Ipobracon rimac* Wolcott and a few adults of the braconid wasp *Bassus stigmaterus* (Cress.) were sent from Peru and liberated on sugarcane plantations in Florida. Surveys made in 1934 by Ingram, Bynum, and Jaynes (Jaynes 1938a) indicated that *Bassus* had become established, but they did not reveal any traces of *Ipobracon*. *Bassus* was subsequently recovered annually from 1935 to 1941, an indication that it has become established in southern Florida.

from stock imported from Cuba and Puerto Rico. The participation of the Bureau in the program is restricted to the provision of some of the parasites for breeding purposes and assistance in observations to determine their effectiveness after liberation in the field.

No specimen of *Bassus stigmaterus*, a species supposed to be established in the area, was found at Fellsmere during the year, although it was present in other localities. Cane from Jupiter, Fla., in which there was a fairly heavy borer parasitization by *B. stigmaterus*, was dumped alongside cane fields at Fellsmere in the fall of 1936 in the hope of establishing this para-

Table 1.—Parasitization of the sugarcane borer by various species of parasites, Fellsmere, Fla., 1941.

Field	Total Number of Borers or Parasites[1] Found in 2 Man-Hours		Percentage of Borers Parasitized by— *Lixophaga Diatraeae*		*Bassus Stigmaterus*		*Metagonistylum Minense*		Total	
	Unemerged Stages	Emerged and Unemerged Stages	Unemerged Stages	Emerged and Unemerged Stages	Unemerged Stages	Emerged and Unemerged Stages	Unemerged Stages	Emerged and Unemerged Stages	Unemerged Stages	Emerged and Unemerged Stages
West										
1	8	39	38.0	30.8	25.0	10.3	12.5	2.6	75.5	43.7
2	4	20	25.0	40.0	25.0	5.0	25.0	5.0	75.0	50.0
3	4	28	25.0	35.7	0	0	0	0	25.0	35.7
Center:										
1	10	48	60.0	66.7	0	8.3	0	4.2	60.0	79.2
2	5	34	60.0	52.9	40.0	11.8	0	0	100.0	64.7
3	13	44	84.6	56.8	0	6.8	0	0	84.6	63.6
East:										
1	12	31	58.3	61.3	0	0	0	0	58.3	61.3
2	6	24	66.7	50.0	0	0	0	0	66.7	50.0
3	7	20	42.9	30.0	0	0	0	0	42.9	30.0
Total or average	69	288	51.2	47.1	10.0	4.7	4.2	1.3	68.1	53.1

[1] Since only one individual of *L. diatraeae*, *B. stigmaterus*, and *M. minense* usually develops within a single host, each parasite found was assumed to represent one borer.

Lixophaga was again received in Florida in 1936 from Puerto Rico (Ingram *et al.* 1939), and recoveries were made at Fellsmere in January 1937, but none were found later in the year.

Beginning in the spring of 1938 the Fellsmere Sugar Producers' Association, in cooperation with the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture, undertook a program of breeding and releasing annually large numbers of sugarcane borer parasites at their Fellsmere plantation, on which about 3000 acres of sugarcane are grown. This work is being done by L. C. Scaramuzza and W. B. Douglas, who in the season of 1938 released 1405 mated females of *Lixophaga*

site. An examination of 10 fields at Fellsmere in October revealed that *Lixophaga* was established in each of these fields, its parasitization ranging from 4.9 per cent, in a field in which no liberation had taken place, to 18.7 per cent. The average parasitization for the 10 fields was 11 per cent. An examination made in cane being harvested in February of the following year revealed an unusually light borer infestation, which was attributed to the work of the parasites.

During the winter of 1938–39 the temperature at Fellsmere dropped to 27° F. for 3 hours, but *Lixophaga*, a tropical parasite, was able to survive, and in April 1939 its parasitization was found to be around 4 per cent in some fields.

Breeding stock was again imported from Cuba and about 800 mated females of *Lixophaga* were liberated during August and September. In addition, 400 individuals of both sexes of another parasite, the Sao Paulo strain of the Amazon fly, *Metagonistylum minense* Towns., were released, 150 of which were brought from Houma, and the rest bred at Fellsmere.

Bassus stigmaterus was noticed in June issuing from the field-collected borers, and in August its average parasitization was 5.6 per cent. In field examinations in July a parasitization of 3.3 per cent by *Bassus* and 8.6 per cent by *Lixophaga* was found. A field examination made in October 1939 revealed that the combined parasitization for the three species was 56.8 per cent, of which 30.6 per cent was due to *Lixophaga*, 21.5 per cent to *Bassus*, and 4.6 per cent to *Metagonistylum*.

During the 1940 season, 1170 mated females of *Lixophaga* were liberated in July and August and 270 flies of both sexes of *Metagonistylum*. *Bassus* was encountered in the fields attacking about 2 per cent of the borers in July, but unfortunately the records of latest field examinations were lost.

In spite of temperatures of 30° F. in November 1940 and 32° in February 1941, both *Lixophaga* and *Bassus* were active in the fields in May, although in small numbers. From the end of May to the beginning of August 1941 there were liberated 3139 mated females of *Lixophaga* and 160 mated females of *Metagonistylum*, reared from stock material imported from Cuba and received from Houma, respectively. With *Bassus* the practice was established of rearing all the larvae issuing from the borers collected in the fields. These borers were collected for infestation with the maggots of the flies. Although these larvae are delicate and succumb easily when handled during the earlier stages, 793 individuals, all females, were reared in this manner and released again in the fields.

By June some fields had a combined parasitization of 10 to 15 per cent due to *Lixophaga* and *Bassus*, but by the middle of October the average combined parasitization was almost 70 per cent, as 81 *Lixophaga* and 40 *Bassus* larvae were dissected or reared from 174 borer larvae collected in 24 field examinations. Of this parasitization 45.4 per cent was credited to *Lixophaga* and 23.0 per cent to *Bassus*.

At the end of September *Metagonistylum* was found attacking only a small percentage of borers, as shown in table 1. This table covers examinations of 2 man-hours in each of 9 fields. During these 18 hours only 18 non-parasitized borers were found.

The increase in parasitization from July to October in three fields is shown in table 2.

Table 2.—Increase in parasitization of sugarcane borer from July to October in three fields, 1941.

Field	Examination Date	Per Cent Parasitization		
		Lixophaga diatraeae	*Bassus stigmaterus*	Total
A	July 15	2.5	2.0	4.5
	Oct. 20[1]	33.3	8.3	41.6
B	July 22	2.6	34.2	36.8
	Oct. 20[2]	25.0	58.3	83.3
C	July 23	16.2	16.2	34.7[3]
	Oct. 21[4]	45.4	36.3	81.7

[1] 132 mated *Lixophaga* females had been released up to July 29.
[2] 63 mated *Lixophaga* females had been released up to July 22.
[3] Includes 2.3 per cent by *Metagonistylum minense*.
[4] 95 mated *Lixophaga* females and 46 mated *Metagonistylum* females had been released between May 26 and June 16.

The parasitization by *Bassus* of 58.3 per cent of the borers found in the second examination of field B is considered the highest ever recorded for this species in sugarcane. A parasitization of 38.8 per cent by this species attacking *Diatraea saccharalis* in rice in Cuba had been reported (Scaramuzza 1932).

It should be mentioned that the fields in which this work has been carried on have an area of approximately 40 acres each and that the number of mated flies released in the colonized fields ranged from 30 to 70, very few fields having received 100 or more.

Whereas the general field infestation at the end of October was estimated at less than 30 per cent of the stalks bored, the bored cane had been damaged at the beginning of the growing season, for the tunnels in the great majority of canes were located in the lower third of the stalk and were old and abandoned. In fact great difficulty was experienced in both the September and October examinations in locating the live borers necessary to obtain the data on parasitization, and in several fields it was impossible to find any live

borers after more than an hour of careful search.

On the other hand, the great abundance of parasites was resulting in the superparasitization of the available host larvae, as indicated by an examination of young ratoons from a field cut for seed. Here it was found that out of the 13 borer larvae collected from "dead hearts" 12, or 92.3 per cent, were parasitized, 10 by *Lixophaga* and 2 by *Bassus*. Of those attacked by *Lixophaga*, 1 borer had 5 living maggots within and 3 borers had 3 maggots each, some already dead, as the borers were small.

During the course of this work it was observed that multiple parasitism may occur between *Lixophaga* and *Bassus*, a phenomenon which can be attributed to the scarcity of hosts. In several instances a maggot of *Lixophaga* and a larva of *Bassus* issued from the same field-collected borer, but neither of the parasites had attained full development and both died before pupation.

Other parasites introduced at Fellsmere, which were not recovered later, include *Apanteles diatraeae* Meus., *Theresia claripalpis* (V. d. W.), and the corn borer parasite *Chelonus annulipes* Wesm.

In June, 1941, 18 small cocoons were found in a tin can with the remains of a *Diatraea saccharalis* larva. The adults were determined by C. F. W. Muesebeck as *Macrocentrus crambi* Ashm., of the family Braconidae, but this species was not found again. In July 1941 several specimens were obtained of a solitary small wasp, which was determined by R. A. Cushman as *Cremastus* sp., of the family Ichneumonidae. Several cocoons were found inside the tunnels of the borer and others issued and pupated at the laboratory from *D. saccharalis* larvae, but the wasp is of no economic importance as yet. —5-11-42.

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NURSERY LAWS AMENDED

Under the 1942 amendments to the Virginia Crop Pest Law, the permit tag is no longer required on nursery-stock shipments to that State, and the Commissioner of Agriculture is authorized to enter into reciprocal agreements with officials of other States as to the payment of registration fees. Woody plants and cuttings and herbaceous plants, including narcissus plants and bulbs, come within the certification requirements.

The Nursery Law of the State of Idaho as amended by the 25th Session of the Legislature revises the definition of nursery and florists' stock to include both woody and herbaceous plants, as well as bulbs, roots, cut flowers, foliage and ferns. No modification is made in the requirements as to nursery bonds and fees.

Two additional treatments for the tomato pinworm have been accepted by the pest-control agencies of Idaho, Oregon, Utah, and Washington, in uniform quarantine amendments adopted in July 1942 on the recommendations of the Western Plant Board. These formulas provide a reduced dosage of atmospheric fumigation with methyl bromide.

The Arizona quarantine relating to the sweetpotato weevil was revised July 14, 1942, to redesignate the infested areas in the various States. A revision of the Arizona quarantine pertaining to the satin moth, adopted July 1, 1942, makes provision for entry of poplars and willows from any infested areas when fumigated according to specifications.

The Mississippi State Plant Board has announced the revocation of Rule 42, pertaining to the alfalfa weevil, which required a permit for shipping hay to that State.

The State of Utah on July 18, 1942, revised the quarantine pertaining to the peach mosaic disease in the seven infected States.

Control of the Tobacco Thrips on Shade-Grown Tobacco in Connecticut[1]

A. W. Morrill, Jr., *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*[2]

Experiments have been conducted at Windsor, Conn., since 1936 in an attempt to find a control measure for use against the tobacco thrips, *Frankliniella fusca* (Hinds), on shade-grown tobacco.

Prior to 1938 preliminary tests were made of two nicotine sprays, a pyrethrum spray, a lauryl thiocyanate spray, a cube spray, and a cube dust. These experiments were laid out in duplicate series and were not suited to statistical analysis. However, the results indicated the desirability of testing some of the materials further. Although none of the insecticides gave satisfactory control, the pyrethrum and cube sprays seemed to give some promise and were selected as a basis for future tests.

In the seasons of 1938, 1939, 1940, and 1941 these tests were combined with tests against the potato flea beetle, *Epitrix cucumeris* (Harr.), in an effort to find a method of obtaining simultaneous control of both insects. The results against the flea beetle have been published (Morrill, 1940).

Methods and Materials.—Six treatments were tested each year on 36 plots arranged in a latin square. Each plot was square and was 1/40 acre in area. The treatments consisted of dusts and sprays containing cube and pyrethrum (Table 1).

The cube dust mixtures were freshly prepared from ground cube root containing 4.5 to 5.2 per cent of rotenone. Sterilized tobacco dust was used as the diluent for all dust mixtures, as it is less conspicuous on the marketed product than are the lighter colored diluents. The micronized cube was commercially prepared from ground cube and tobacco dust and contained about 3 per cent of sand added as an abrasive during the micronizing process. The pyrethrum dust mixtures were commercially prepared by coating or "impregnating" exhausted pyrethrum flowers with the active principles of pyrethrum and about 0.2 per cent of a petroleum oil. The pyrethrum extract contained 2.4 per cent of pyrethrins and the derris extract 3.1 per cent of rotenone. Two conditioning agents were used. Conditioner "A" was a water-soluble sulfonate of petroleum hydrocarbons and was used at the rate of 1 ounce to 100 ounces of dust mixture and 4 ounces to 50 gallons of spray mixture. Conditioner "B" was a sodium salt of an alkylated naphthalene sulfonic acid and was used in the same manner as conditioner "A." In the cube spray mixtures the ground cube was used at the rate of 1 pound per 50 gallons of water. In spray mixtures containing both rotenone and pyrethrins the ground cube was used at the rate of 1 pound to 100 gallons of water.

The dusts were applied between 7 and 9 A.M., when wind movement is low in the region of Windsor. They were applied with hand-operated rotary dusters at rates of 5 to 12 pounds per acre as the plants increased in size. The sprays were applied immediately after treatment of the dusted plots was completed. They were applied with knapsack sprayers capable of 150 pounds' pressure at rates of 30 to 80 gallons per acre as the plants became larger. Applications were made twice weekly, and population counts were made of the live thrips present on the leaves of 10 plants selected at random in each plot. These counts were made 24 hours after each application and again immediately prior to the following application.

Methods of determining the amount of thrips injury to the cured tobacco leaf were modified slightly as the work progressed. In 1938 only injury that extended beyond the midrib area into the commercially useful portion of the leaf was counted (Fig. 1). In 1939, 1940, and 1941 this injury was termed "damage," and injury confined to the midrib, where the thrips habitually remains, was recorded separately.

The 12 commercially most valuable leaves were harvested from 10 plants selected at random from each plot. In accordance with commercial practice, these leaves were taken 3 at a time at intervals of about a week, the primings commencing at the bottom of the plant and proceeding upward as the leaves ripened. These

[1] Eastern Branch Program Paper, Baltimore, 1941.

[2] In cooperation with the Connecticut Agricultural Experiment Station.

Table 1.—Effectiveness of various insecticidal treatments in the control of the tobacco thrips in shade-grown tobacco.

TREATMENT	DOSAGE PER ACRE PER APPLICATION	LIVING THRIPS ON SAMPLE PLANTS	LEAVES INJURED PER CENT	WRAPPERS DAMAGED PER CENT
1938, 12 applications				
Cube dust (1% rotenone)	10.0 lb.	165.5	29.8	—
Cube dust (1.3% rotenone)	8.4 lb.	160.5	23.1	—
Cube dust with conditioner "A" (1% rotenone)	9.6 lb.	121.0	22.6	—
Cube spray with conditioner "A" (0.011% rotenone)	57.6 gal.	156.0	18.0	—
Cube spray with conditioner "B" (0.011% rotenone)	57.8 gal.	156.5	32.0	—
Check	—	239.5	43.2	—
Significant difference		(1)	23	
1939, 11 applications				
Cube dust (1% rotenone)	10.1 lb.	181	64.4	19.5
Cube dust with conditioner "A" (1% rotenone)	11.2 lb.	159	76.7	26.6
Pyrethrum dust "impregnated" (1% total pyrethrins)	8.9 lb.	30	46.7	6.5
Cube spray with conditioner "A" (0.012% rotenone)	62.0 gal.	143	69.0	20.3
Cube-pyrethrum extract-sulfated castor oil spray (0.006% rotenone, 0.008% total pyrethrins, 0.3% oil)	62.6 gal.	101	65.9	14.3
Check	—	138	70.3	20.6
Significant difference		71.9	17.0	11.6
1940, 7 applications				
Cube dust (1% rotenone)	8.6 lb.	77	26.4	31.5
Pyrethrum dust "impregnated" (0.5% total pyrethrins)	8.4 lb.	68	7.3	7.4
Cube and pyrethrum dusts applied alternately	8.6 lb.	50	17.9	12.1
Derris extract-pyrethrum extract-glycerol (0.003% rotenone, 0.008% total pyrethrins, 3% glycerol)	36.6 gal.	82	32.7	31.7
Cube-pyrethrum extract-sulfated castor oil spray (0.006% rotenone, 0.008% total pyrethrins, 0.3% oil)	37.1 gal.	76	29.0	26.4
Check	—	140	47.3	59.9
Significant difference		(1)	7.4	18.4
1941, 8 applications				
Cube dust (1% rotenone)	8.7 lb.	265	45.0	12.2
Pyrethrum dust "impregnated" (0.4% total pyrethrins)	8.7 lb.	158	24.0	1.7
Cube and pyrethrum dusts applied alternately	9.0 lb.	268	25.6	5.5
Cube dust with conditioner "A" (1% rotenone)	7.4 lb.	414	40.0	10.5
Cube dust "micronized" (1% rotenone)	8.8 lb.	325	28.1	8.0
Check	—	588	63.7	19.1
Significant difference		225	16.15	5.61

[1] The difference required for significance was not computed because the F test showed that the observed differences were not significant.

leaves were cured, fermented, and processed together with the rest of the crop. Each leaf was then examined closely for evidence of thrips injury and graded according to the severity of the damage. For this purpose the number of cigar wrappers rendered useless was recorded, on the basis of a normal yield of 4 per leaf (Morrill & Lacroix 1940).

RESULTS.—The results are shown in table 1. Of the materials tested in 1938 the best control was obtained with cube spray. None of the differences between treatments was significant, however, although the difference between the abovementioned treatment and no treatment was significant.

In 1939 the reduction of population in the plots treated with pyrethrum dust was striking, whereas in other plots no apparent reduction occurred. The season was abnormally dry, a condition favorable

to a large population of, and heavy damage by, this insect. Damage apparent after the leaves were cured was also significantly less with this material than with the cube materials or the sprays, although the cube dust and spray were better than no treatment.

During the first part of the 1940 season precipitation was more nearly normal and population counts were low, but not greatly lower in the plots dusted with pyrethrum than in the other plots. A

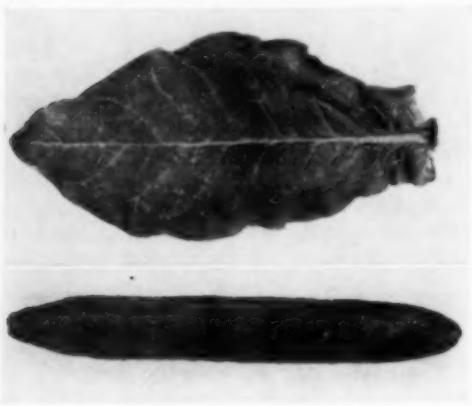

FIG. 1.—Green leaf of tobacco, showing the white veining caused by thrips feeding, and cigar wrapped with a leaf injured by thrips feeding, also showing white streaking.

month of drought concluded the season, however, and populations increased late in July. Examination of cured leaves again revealed appreciably less damage in the plots dusted with pyrethrum (Morrill & Lacroix 1941).

In 1941, because of the impracticability of applying them, sprays were abandoned, and the test materials included cube dust, "micronized" cube dust, cube dust containing a conditioning agent, and pyrethrum dust. This season was in general abnormally dry but there occurred several severe storms which nearly obliterated the insect populations for several days. The application of dusts was difficult not only because of the rain itself, but also because of the tangled condition of the tobacco after these storms. Before large or stable insect populations could become established the tobacco was too large to permit further dust applications. Nevertheless, the population counts on the plots dusted with pyrethrum were only a little more than half those on other treated plots and somewhat more than one-fourth those on the untreated plots. Damage to wrappers under these adverse control conditions amounted to considerably less in plots dusted with pyrethrum than in those dusted with cube.

PRESENT STATUS OF CONTROL PROBLEM.—The use of sprays is not considered feasible at this time because of the greater difficulty of obtaining adequate coverage of fully grown plants without causing excessive damage to the interlaced leaves. Tartar emetic-brown sugar spray, which gives good thrips control on other crops, cannot be used on tobacco because of the residue. Although tobacco is not a food or a drug, it is taken into the mouth, and poisonous or unpleasant residues must be avoided. Also, from a marketing standpoint, there must be no potentially adverse effect on its color, texture, or odor.

Feeding by thrips affects the appearance of the tobacco. Severe feeding causes it to become papery and lifeless, destroying its value for use as cigar wrappers, and even moderate feeding causes a white veining that gives a longitudinal streaking to the cigar (Fig. 1). Since the potential value of the crop is high, such injury occasions a heavy loss to the grower. Control that is merely sufficient to restrict the thrips to the discarded midrib portion of the leaf is therefore of practical value to the grower. Pyrethrum seems to be more effective in this respect than cube or any other material tested.

SUMMARY.—Experiments have been conducted since 1936 on the control of the tobacco thrips, *Frankliniella fusca* (Hinds), on shade-grown tobacco in Windsor, Conn. None of the materials tested in 1936 and 1937 gave satisfactory control. In 1938, 1939, 1940, and 1941 the materials tested included cube-tobacco dust containing 1 per cent of rotenone, with and without a conditioning agent, cube dust and a conditioning agent applied as a spray, sprays containing pyrethrum extract with sulfated castor oil and with glycerol, and "impregnated" pyrethrum dust containing 0.5 per cent of total pyrethrins. These materials were applied to fortieth-acre plots each replicated 6 times in a latin square arrangement. The pyrethrum dust caused a significantly greater reduction of thrips population and also a significantly greater reduction of damage to the cured leaves resulting from thrips

feeding. Although this material does not give complete control and has been somewhat expensive by comparison with other insecticidal materials used in this region, the reduction in loss is sufficient to make its use practicable.—4-24-42.

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The Place of Concentrated Sprays in the Pea Aphid Control Program[1,2]

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Conventional spraying as applied to the pea aphid problem has in many cases been found to give a relatively high degree of control. This type of spraying should therefore have assumed an important place in the general pea aphid control program but for the almost impossible task of supplying the volume of water required for the large scale operations that are involved in the treating of cannery peas. As it is, this burden, together with other handicaps peculiar to most spraying operations, such as cost, slowness of operation, and weight of equipment has rendered this otherwise promising method of control all but obsolete so far as cannery peas are concerned. In view of this situation the effort that has been expended not only by official workers in different parts of the country but by insecticide and machinery manufacturers in an attempt to develop a more rapid, less cumbersome system of spraying peas can readily be appreciated.

The general idea of reducing or even doing away entirely with the inert carriers that are ordinarily regarded as essential to the proper functioning of most of our common insecticides is one that is logical and that has always had a strong appeal. The fact, however, that more lasting progress has not been made in the practical application of this principle would seem to indicate that the problems involved are by no means as simple as some may have been led to believe. This assumption is fully borne out by field experience, for while truly remarkable progress has been made in adapting the principle of concentrated spraying to pea aphid control, it must be admitted that the practical value of this method for treating cannery peas is still very much a subject of debate.

Our own interest in this phase of the pea aphid problem has centered largely in a group of canners who quite frankly were willing to accept a degree of control considerably short of perfect but who were in no way interested in methods requiring the application of more than 20 or 30 gallons to the acre or where the machines used in making the applications had to travel at a speed under 4 or 5 miles per hour.

During the past 5 years, as part of our regular pea aphid research program, studies have been carried out with the object of determining the practicability of using highly concentrated sprays on the chance that this method might be found to give passable control and at the same time avoid some of the serious weaknesses that have practically ruled out regular spraying so far as our New York pea-canners are concerned.

[1] Eastern Branch Program, Baltimore, 1941. Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper No. 179, November 20, 1941.

[2] The findings reported in this paper were made possible largely as a result of the whole-hearted cooperation of men in the organization of the Snider Packing Corporation, Rochester, New York, and through the able assistance given throughout the 1941 season by Mr. William Ralston of the Research Department of the Tobacco By-Products and Chemical Corporation, Richmond, Virginia.

This phase of the work has been carried out almost entirely in cooperation with the Snider Packing Corporation, and it has been largely due to the vision of the men in this organization and to their eagerness to find some rapid, reasonably effective method for fighting the pea aphid that our studies on this aspect of the problem have been followed through as persistently as they have.

At the outset light oils impregnated with various contact insecticides were used, although water-borne sprays were also tested to come extent. Most of the earlier applications were made by airplane or autogiro supplemented by a rather primitive type of ground-operated machine which utilized the blower of a Bean duster for "atomizing" the spray. After two years' experience with airplanes it became apparent that the degree of control that could be expected from the airplane did not seem to justify the continued use of this type of equipment and emphasis thereafter was shifted largely to ground-operated machines.

The earlier types of ground machines gave even poorer control than the airplanes, but as there appeared to be abundant opportunity for improving the performance of the ground machines and not so much that could be done in the case of the airplane, attention during the past three seasons has been directed mainly toward this method of applying the concentrated sprays.

During the course of the work there has been abundant opportunity for observing the performance of a number of commercial "atomizers," some of which were found to possess many excellent features, but most of the results to be discussed at this time are based on field work carried out with a machine built locally by the Snider Packing Corporation that has been developed and improved from year to year as the work progressed. Briefly, this machine as it now stands, unlike most of the so-called "atomizers" is operated by direct pressure from a standard spray unit which has remained essentially the same from the beginning, the chief modifications having been made in the boom construction and in the type of nozzle used.

Since the spray from this machine is delivered in a very finely divided state, in the absence of any supplementary air blast to give it carrying power, it was found necessary to adopt a special boom construction and nozzle arrangement (Fig. 1) so that the nozzles could be carried almost at the level of the tops of the peas. Even then a hood completely enclosing the boom was found almost essential where oil sprays were used, while in addition to this protection a trailer (Fig. 2) greatly improved the performance of the water-borne sprays, particularly those depending on nicotine as the killing agent.

The boom, as illustrated in figure 1, is 22 feet long, and is made of parallel three-quarter-inch pipes spaced approximately 14 inches apart, on which are placed at intervals of 12 inches a total of 42 standard

FIG. 1.—Boom construction and nozzle arrangement used on Snider machine for applying concentrated sprays in pea aphid control.

oil burner nozzles. These nozzles are set at a low angle and are directed so that the cones of spray cut into the edges of the cones from the corresponding nozzles on the opposite side of the boom. This nozzle arrangement has been found necessary to insure adequate coverage on a broadcast crop such as canning peas.

The possibility of substituting water for the light oils originally used as the carrier of the insecticide received considerable attention during the course of these studies on account of the foliage injury occasionally resulting from excessive applications

of the oil sprays and also because it seemed logical to expect more complete coverage with the greater volume that could safely be used in the case of water sprays. In tables 1 to 3 will be found the summarized results of three representative field tests where concentrated sprays were applied against the pea aphid during the 1941 season. A study of these tables will serve to indicate the degree of control that it has been possible to get with certain types of concentrated sprays applied under favorable conditions by means of the machine just described.

FIG. 2.—Forty-foot trailer essential in the application of concentrated water spray.

The variety in all these fields was Perfection, the stands all being practically perfect with no indication of root troubles or other diseases in any of the fields. The first two fields were located on the Genesee Valley flats where the soil was exceptionally fertile and level. The third field (Table 3) was on typical upland soil.

The comparisons shown in these tables are all based on direct population counts. These counts were made according to a method that has been followed for a number of years in all our pea aphid studies, the technique of which has been described in an earlier paper (Glasgow 1939) and represent in each case the number of aphids of all sizes actually taken in 10 strokes of an 11-inch beating net equipped with a 26-inch handle. In all cases the counts recorded represent the average of three identical collections taken at widely separated points in the same plot. It should perhaps be emphasized at this time that population counts taken in this way have been found by repeated checking to be surprisingly consistent, any serious variation being usually traceable to some source other than the method of collecting and counting. This assumes, of course, that an honest effort is made by the operator to see that the field collections are taken in such a way that they will be really comparable.

The planting on which table 1 is based was a 20-acre field divided into the six plots as indicated. Those plots treated by the vapofumer and rotenone dust are included in the table to serve as a further basis for comparison. All the treatments in this field were put on under exceptionally favorable conditions. Treatments were made approximately a week or ten days before bloom at a time when the aphid population averaged higher than 5000 individuals in 10 strokes of the collecting net. When the regular counts were made, 9 days after the last of the treatments were applied, the general population level had dropped to 2848. Incidentally this decline continued consistently as the season progressed. Needless to say the showing made by some of the treatments might have been much less favorable if the population trend, as frequently happens, had been in the opposite direction.

FIG. 3.—Application of concentrated sprays by airplane.

Notwithstanding the heavy initial infestation in this field, the untreated plot yielded at the rate of 1404 pounds per acre as compared with 2753 pounds for the highest yielding treated plot. The striking thing about this series is the relatively high kill shown by the oil spray, the kill in this case being comparable to that given by the vapofumer, which ordinarily is expected to lead all other methods in efficiency.

The water-borne sprays in this series, while giving passable control, were distinctly inferior to the oil spray, although here the results might well have been more favorable if the trailer had been used.

Table 2 represents an 8-acre field which was divided into three plots as indicated. Treatments were completed in this field on June 8 at which time the population recorded was 12,160. Successive counts were made at intervals of 9, 12, and 17 days following treatment. The fluctuation in the general population level of this field is clearly shown by these successive counts. It should be pointed out here that the aphid population in the sprayed block remained at a relatively high level much longer than in the case of the vapofumer and this, together with the fact that the spray was applied a day later than the vapofumer treatment may account in part for the difference in yield, 1429 pounds per acre in the case of the oil spray as compared with 1921 pounds for the vapofumer, and 683 pounds for the untreated block.

Table 1.—Efficiency of concentrated sprays as measured by pea aphid control (Cole Brothers field).

Treatment[1]	Dosage per Acre	Operating Speed (Miles per Hour)	Aphid Population[2]	Reduction Per Cent
Vapofumer	3 lbs.	1	207	92.7
Rotenone dust	45 lbs.	1	589	79.3
Spray No. 1 (water)	20 gals.	5	576	79.8
Spray No. 2 (water)	20 gals.	5	383	86.5
Spray No. 3 (oil)	5 gals.	5	172	94.0
Untreated	—	—	2848	—

[1] Vapofumer—80% free nicotine.
Rotenone dust—1% rotenone, 2% soybean oil, pyrophyllite.
Spray No. 1—96¼ gallons water, 3¼ gallons of a 2½% rotenone extract.
Spray No. 2—96 gallons water, 1½ gallons *Black Leaf 40*, 18 lbs. soap.
Spray No. 3—89¼ gallons oil (35 viscosity), 1¼ gallons 80% free nicotine, 9 gallons of a 2½% rotenone extract.
[2] Population counts taken 9 days after treatments were completed.

In dealing with an overwhelming infestation such as was present in this field it may be that even a slight delay in starting treatment or the slowness of the aphid population to respond to a given treatment might well be reflected in the final yield even though ultimately, as in this case, it was reduced to practically the same level in both the treated plots. Nine days after the oil treatment was applied the number of aphids had practically doubled in the untreated section of the field and many of the plants in this area had commenced to show the browning of the tips characteristic of severe aphid injury which was readily apparent even from a considerable distance. Within the next 3 days the population had dropped to practically the original figure, while in 4 more days there was a further decrease of over 60 per cent, although even at that figure the population obviously was still heavy enough to cause serious injury, as evidenced by the ultimate destruction of the plants in some areas of the untreated section of the field. If it had not been for this consistent downward trend the untreated sections would certainly have been a complete loss and the treated areas might well have made a much poorer showing than they did.

In the series of tests recorded in table 3 the applications were made June 19 and the counts on which the table is based were taken 7 days later on June 26. Counts made within a few days after spraying showed a marked difference in the case of the first three water-sprayed plots in favor of No. 2 and No. 3, the reduction in the case of No. 3 being particularly striking, although at the end of 7 days these differences had been largely smoothed out.

The poor showing made by the oil sprays in this field may be accounted for in part by the conditions under which they were applied. In this case the wind velocity was between 8 and 9 miles where, earlier in the day, at the time the water sprays were applied, it was somewhat less that 3 miles per hour.

SUMMARY.—Concentrated sprays when applied to cannery peas have in many cases given us a relatively high degree of control. This has been true not only in our own experimental work but also where such sprays have been used on a commercial basis in the hands of experienced canners. There are, however, at present certain very definite limitations to this method of application that it would be well to keep clearly in mind.

In some combinations, particularly where oils are used as the carrier, the concentration of the spray may be so great that foliage injury occasionally results, or in any case the margin of safety is likely to be perilously narrow. There is also the possibility, by no means established however, of such highly concentrated sprays exerting a retarding influence on the crop that may be reflected in the final yield even though no noticeable injury is apparent at the time of application. At times also it has been noted that on extremely hot, windy days the water sprays seem to evaporate so rapidly before even reaching

Table 2.—Efficiency of Concentrated Sprays as Measured by Pea Aphid Control (Banker and Wadsworth Field).

TREATMENT[1]	APHID POPULATION	REDUCTION PER CENT	APHID POPULATION	REDUCTION PER CENT	APHID POPULATION	RECUCTION PER CENT
Counts made	June 17		June 20		June 25	
Vapofumer	367	98.2	327	97.6	265	94.4
Spray (oil)	1,267	93.8	381	97.2	218	95.4
Untreated	20,544	—	13,579	—	4,727	—

[1] Treatments completed June 8 at which time the aphid population recorded was 12,160.
Vapofumer—3 pounds 80% free nicotine per acre.
Spray —5 gallons per acre of the following spray: 89.5 gallons oil (35° viscosity), 1.5 gallons 80% free nicotine, 9 gallons of a 2.5 % rotenone extract.

the plants that the kill is greatly reduced.

In order to insure anything approaching adequate coverage at the greatly reduced volume ordinarily used in sprays of this type, the sprays must necessarily be broken up into a very fine, mist-like condition. Since such sprays closely approximate dusts in many of their physical properties, the difficulty of protecting them from displacement by air currents during application and of insuring uniform coverage is much greater than in the case of conventional spraying. This weakness, while partly compensated for in some types of equipment by a supplementary air blast designed to carry the finely divided spray into the foliage, or by equipping the boom with protecting hoods or baffles to minimize the effects of air currents, is still unquestionably the most serious obstacle in the way of a more general acceptance of this method of application. While this method of spraying has certainly not been finally perfected either as to the most effective insecticide combination or the best equipment to use, the results so far have been promising enough to merit further serious consideration by both the investigstor and the canner.

Unquestionably there are still glaring weaknesses in the method but when the advances that have been made in the last few years, particularly in the development of equipment adapted to the application of this type of sprays are taken into account, and the possibilities for still further improvement, are recognized, it is apparent that the method does have real possibilities as a means of treating cannery peas for aphid control.—11-24-42.

Table 3.—Efficiency of concentrated sprays as measured by pea aphid control (Kirkwood field).

TREATMENT[1]	GALLONS PER ACRE	OPERATING SPEED (MILES PER HOUR)	APHID POPULATION (AFTER 7 DAYS)	REDUCTION PER CENT
No. 1 (water)	20	5	423	95.5
No. 2 (water)	20	5	352	96.4
No. 3 (water)	40	5	231	97.5
No. 4 (oil)	5	5	1357	85.5
No. 5 (oil)	5	5	1337	85.7
Untreated	—	—	9363	—

[1] Spray No. 1—water 94 gallons, nicotine sulfate 15 pints, soap 30 pounds, without trailer.
Spray No. 2—Same as No. 1 but with 40-foot trailer.
Spray No. 3—Same as No. 2 but application repeated immediately with machine moving in opposite direction.
Spray No. 4—oil (35 viscosity) 89¼ gallons, 2½% rotenone extract 9 gallons, 80% free nicotine 1½ gallons.
Spray No. 5—oil (35 viscosity) 96¼ gallons, 80% free nicotine 3¾ gallons.

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Certification requirements for certain articles restricted under the white-fringed beetle quarantine were waived until February 1, 1943, under administrative instructions of the Chief of the Bureau of Entomology and Plant Quarantine (Circular B.E.P.Q. 485, 10th revision effective August 3, 1942).

The Control of Pillbugs and Sowbugs

R. M. Bohart and A. Mallis,[1] *University of California, Los Angeles*

The common pillbug, *Armadillidium vulgare* (Latreille) and the dooryard sowbug, *Porcellio laevis* Koch have worldwide distribution. These terrestrial isopods are well known as pests in gardens, lathhouses and greenhouses where they are particularly injurious to seedlings. Under favorable conditions they may attack field crops, especially the legumes, and in the San Joaquin Valley of California they have been reported injurious to cotton seedlings following alfalfa in rotation. Although practically omnivorous, their normal diet consists chiefly of decaying vegetable matter. This accounts for their abundance under rank herbage where organic matter has accumulated. In greenhouses in addition to their injury to seedlings, they are often a general nuisance crushing underfoot along the walks, separating the earth from the sides of the benches so as to cause uneven drainage, devouring fertilizers as fast as they are applied, and girdling plants at or near the ground level. They also enter the realm of household pests when, as not infrequently happens, they congregate in large numbers in the moist basement of dwellings.

Review of Literature.—Very little scientific information has been published on the life history and control of pillbugs and sowbugs. The paper giving the most detailed information was one by Pierce (1907) who emphasized the relationship of these pests to cotton in Texas. He made notes on life history, habits and control; and recommended for *A. vulgare* the standard remedy of that time, potatoes poisoned with paris green or london purple; the use of paris green sprinkled around plants or dusted under boards; and clean culture.

Collinge (1914) recommended the use of a kerosene emulsion, paris green or london purple in potatoes, or paris green and unslaked lime in equal parts dusted over the soil.

Speyer (1923) advocated flooding infested areas in greenhouses with hot water and spraying the surface of the water with naphthalene emulsion. In two subsequent papers, Speyer (1925, 1926) suggested using either a paris green-oatmeal bait (oatmeal 90 parts, white flour 5 parts, paris green 5 parts) or a paris green-bran bait (1 part paris green to 28 parts bran, the mixture to be used at the rate of a half-ounce to the square yard).

The most extensive tests using different chemicals were made by Thompson (1932). Materials found very effective in the laboratory were paradichlorobenzene dusted over the soil, paris green-icing sugar bait (1 part to 20 parts by volume), paris green bran bait, sodium arsenate-bran bait, and mercuric chloride solution (1 to 1000). Partially effective were naphthalene flakes dusted over the soil, oil sprays, sodium fluoride-icing sugar bait (1 part to 20 parts by volume), sodium fluoride solution (1 to 160), sodium fluosilicate solution (1 to 160), and pyrethrum sprays. Ineffective, were derris as a powder or spray, dry sulfur as a barrier, calcium chloride as a barrier, sodium arsenate solution (1 to 160), and copper sulfate solution (1 to 80).

Weigel (1933) recommended the use in greenhouses of poisoned bran mash; paris green and sugar (1 to 9); or paris green, 1 part, white flour, 2 parts, and sugar, 2 parts, sprinkled lightly over the soil. Dry tobacco dust was suggested as a repellent. The use of a kerosene-nicotine oleate spray under benches and on walks was also mentioned.

Laboratory Experiments on Control.—A series of laboratory tests were conducted from December, 1940 to May, 1941, in an attempt to evaluate the relative toxicity to pillbugs of various materials which might be applied as dusts over infested areas. Pillbugs were used because preliminary experiments definitely showed that sowbugs reacted in essentially the same manner but were much easier to kill. In addition pillbugs are chiefly responsible for commercial injury, and they are easier to handle in the laboratory.

Stender preparation dishes with ground glass tops and with a bottom area of 7 square inches were used throughout the experiment. Fifty mature pillbugs were placed in each dish and covered with 50 grams of moist earth which was then dusted with weighed amounts of insecti-

[1] Substantial aid in the laboratory was contributed by R. J. Pence.

Table 1.—Laboratory toxicity tests on pillbugs.

MATERIAL USED PER 1000 SQ. FT.	FLOUR ADDED PER 1000 SQ. FT.	TOTAL PILLSBUGS USED[1]	PER CENT MORTALITY[2]		
			1 Week	2 Weeks	3 Weeks
Sodium arsenite					
5.0 lbs.	5 lbs.	100	100	100	100
0.5	5	100	72	86	92
Paris Green					
25.0 lbs.	—	50	100	100	100
5.0	25 lbs.	50	98	100	100
5.0	5	100	100	100	100
2.5	25	50	98	100	100
1.0	5	100	95	99	99
0.5	25	50	84	86	86
White arsenic					
5.0 lbs.	5 lbs.	100	89	94	97
Sodium arsenate					
5.0 lbs.	5 lbs.	100	100	100	100
0.5	5	100	50	57	68
Manganese arsenate					
5.0 lbs.	5 lbs.	100	100	100	100
0.5	5	100	40	52	52
Calcium arsenate[3]					
25.0 lbs.	—	75	100	100	100
5.0	25 lbs.	50	94	100	100
5.0	5	100	98	100	100
4.0	5	100	99	100	100
3.0	5	100	99	99	100
2.0	5	100	81	95	99
2.0	—	100	88	99	100
1.0	5	100	80	94	96
1.0	—	100	76	91	96
0.5	25	50	18	34	40
Acid lead arsenate					
25.0 lbs.	25 lbs.	80	98	99	100
25.0	—	75	41	85	99
10.0	5	100	96	97	100
5.0	25	50	68	82	82
5.0	5	100	71	77	83
2.5	25	50	16	26	34
0.5	25	50	6	12	16
Basic lead arsenate					
5.0 lbs.	25 lbs.	50	8	12	14
5.0	5	100	7	9	15
2.5	25	50	12	16	20
0.5	25	50	0	10	16
Mercuric chloride					
5.0 lbs.	5 lbs.	100	100	100	100
0.2	5	100	57	73	93
Mercurous chloride					
5.0 lbs.	5 lbs.	100	100	100	100
0.5	5	100	59	80	84
Cuprous cyanide					
5.0 lbs.	5 lbs.	100	99	100	100
2.5	5	100	96	99	99
1.0	5	100	72	77	81
Cuprous carbonate					
5.0	5 lbs.	100	31	57	82

Material Used For 1000 Sq. Ft.	Flour Added Per 1000 Sq. Ft.	Total Pillbugs Used[1]	Per Cent Mortality		
			1 Week	2 Weeks	3 Weeks
Tartar emetic					
25.0 lbs.	25 lbs.	19*	21	21	26
5.0	5	100	11	17	21
Sodium fluosilicate					
5.0 lbs.	5 lbs.	100	33	45	64
Sodium fluoride					
25.0 lbs.	25 lbs.	25*	40	68	76
5.0	5	100	15	27	27
Cryolite (natural)					
25.0 lbs.	25 lbs.	25*	0	4	8
5.0	5	100	3	5	8
DND[4]					
25.0 lbs.	25 lbs.	26*	32	42	59
5.0	5	100	24	33	34
Nicotine-bentonite (5% nicotine)					
5.0 lbs.	5 lbs.	100	4	9	16
Nicotine dust (10% nic. sulfate)					
5.0 lbs.	5 lbs.	100	10	14	16
Pyrethrum dust A (0.75% pyrethrins)					
25.0 lbs.	25 lbs.	77	79	95	95
Pyrethrum dust B (0.2% pyrethrins)					
5.0 lbs.	5 lbs.	100	52	62	67
Derris dust A (5% rotenone)					
25.0 lbs.	25 lbs.	5*	0	0	0
Derris dust B (23% extractives)					
5.0 lbs.	5 lbs.	100	6	10	16
Phenothiazine					
5.0 lbs.	5 lbs.	100	13	19	36
Sulfur (flowers)					
5.0 lbs.	5 lbs.	100	10	16	19
Hydrated lime			10		
5.0 lbs.	5 lbs.	100	100	20	33
Check					
—	5 lbs.	818	9	16	27

[1] Numbers followed by an asterisk represent a single test. All others are the sum of two tests except the check which is the sum of 19 tests.
[2] Calculated to the nearest whole number.
[3] Commercial calcium arsenate, active ingredients calcium arsenate 70 per cent.
[4] Trade name for the dicyclohexylamine salt of dinitro-o-cyclohexylphenol.

cide. Food was present in the form of organic matter in the earth and when necessary, blades of grass were added. The moisture in the nearly air-tight dishes was supplemented occasionally. Under these conditions a tendency to cannibalism was observed, particularly when the victims were in the process of molting or generation. However, in a long series of checks the resulting mortality was remarkably

constant, approximating 9 per cent after one week, 16 per cent after two weeks, and 27 per cent at the end of three weeks.

A study of table 1 reveals several salient points. Using the concentration of 5 pounds to 1000 square feet as a standard, materials found ineffective were basic lead arsenate, tartar emetic, sodium fluoride, natural cryolite, *DND4* (dicyclohexylamine dinitro-o-cyclohexylphenate), nicotine-bentonite (5 per cent nicotine), nicotine sulfate dust (10 per cent nicotine sulfate), derris dust (23 per cent extractives), phenothiazine, flowers of sulfur, and hydrated lime. Partially effective, with mortalities at the end of the three weeks period ranging from 64 to 83 per cent were acid lead arsenate, copper carbonate, sodium fluosilicate, and pyrethrum dust (0.2 per cent pyrethrins). Highly lethal at the rate of 5 pounds to 1000 square feet and arranged in descending order of toxicity based on mortality at lower dosages were mercuric chloride, sodium arsenite, paris green, mercurous chloride, sodium arsenate, manganese arsenate, calcium arsenate, copper cyanide, and white arsenic.

At effective concentrations all of the last mentioned materials except manganese arsenate, calcium arsenate, and copper cyanide are dangerous to use where plants are concerned. Also, the high cost of the mercury compounds, copper cyanide, and manganese arsenate are not in their favor. It is interesting to note that mercuric chloride is markedly toxic to pillbugs even at the low dosage at which it is recommended for fungus diseases on lawns (0.2 pounds per 1000 square feet). Calcium arsenate appears to be the only material that combines the advantage of low cost, low toxicity to plants, and high toxicity to pillbugs.

Flour was used as a diluent, adhesive, and attractant. Its effect was most pronounced in the acid lead arsenate tests. According to table 1 its presence accelerated the kill, although it did not seem to affect the final mortality. The use of 25 pounds to 1000 square feet instead of 5 pounds gave slightly inferior results in every case. This was presumably due to an excessive dilution of the poison.

The rapidity with which pillbugs succumbed on exposure to paris green suggested that laboratory tests be conducted to determine whether any contact action was involved. Three insecticides, paris green, calcium arsenate, and cuprous cyanide, were employed in the experiment, and one hundred pillbugs were used with each insecticide. A check of 100 pillbugs was maintained throughout the test. The pillbugs were marked on the underside between the fourth pair of legs with a single dot from a water paste of each of the insecticides. The pillbugs were then placed separately in syracuse watch glasses and provided with moist earth and food. The weight of the dots used varied from 0.013 to 0.02 milligrams.

After 7 days the per cent mortality was 86, 81, 41, and 22, for paris green, cuprous cyanide, calcium arsenate, and the check, respectively. It may thus be concluded that all of the materials are effective as contact poisons against the pillbug, but in varying degree.

In this experiment it was noted that pillbugs rubbed the poisons off to some extent and particles could be found scattered in the earth. To investigate the likelihood of error from possible ingestion of dislodged poison, 15 dishes with half a dozen particles of paris green distributed in each were examined over a period of a week. At the end of this time all 15 pillbugs appeared in healthy condition.

FIELD EXPERIMENTS ON CONTROL.—The present widely used paris green bait method of control has several obvious disadvantages. Watering quickly dissolves and washes away sugar if this material is used as the attractant. When bran or vegetable meals are used with paris green they quickly mold in the naturally moist environment in which treatment is usually made. Furthermore, the bait method is effective only insofar as pillbugs are attracted and there is always a considerable percentage which the bait fails to lure.

Calcium arsenate dust is somewhat more difficult to apply than a bait, but it eliminates the disadvantages of the latter listed above. A preliminary field test was made in March 1941 on the infested grounds of a private home. Calcium arsenate was used as a dust at the rate of 3 pounds to 1000 square feet. An equal amount of white flour was added. Although the treatment was followed on the next and succeeding days by heavy rains, the result was very promising. An estimated 99 per cent control was obtained and no damage was noted to any of a variety of plants in-

cluding blue grass, begonias, ferns, violets, and english ivy. In severely infested spots 2 weeks after treatment the ground was literally white with the bleached skeletons of dead pillbugs and sowbugs. In June, 1940 the grounds were again inspected. Only an occasional pillbug was found, indicating that reinfestation had not taken place as late as three months after application. Subsequent experiments with calcium arsenate dust in nurseries and on the grounds of homes gave encouraging results. From these tests the following points were indicated: (1) Treatment was most successful from April to June, the period of greatest pillbug activity. (2) More than one application was necessary when reinfestation of treated areas was caused by the drying up of adjacent fields. (3) No appreciable difference was observed between the use of calcium arsenate alone or with flour. (4) Best results were obtained with the use of 3 to 5 pounds of calcium arsenate to 1000 square feet.

SUMMARY —Although pillbugs (*Armadillidium vulgare*) and sowbugs (*Porcellio* spp.) are minor and occasionally major pests of the greenhouse, garden, field, and household, little information has been published on their life history and control. The relative toxicity to pillbugs of 26 different materials was measured in a series of laboratory tests. At a concentration of 5 pounds to 1000 square feet materials found ineffective were basic lead arsenate, tartar emetic, sodium fluoride, natural cryolite, dicyclohexylamine dinitro-o-cyclohexylphenate, nicotine bentonite (5 per cent nicotine), nicotine sulfate dust (10 per cent nicotine sulfate), derris dust (two mixtures), phenothiazine, sulfur dust, and hydrated lime. Partially effective (64 to 83 per cent mortality after three weeks) were acid lead arsenate, copper carbonate, sodium fluosilicate, and pyrethrum dust (0.2 per cent pyrethrins). Highly lethal at 5 pounds to 1000 square feet and arranged in descending order of toxicity based on lower dosages were mercuric chloride, sodium arsenite, paris green, mercurous chloride, sodium arsenate, manganese arsenate, calcium arsenate, copper cyanide, and white arsenic. Of these calcium arsenate appears to be the most practical from the standpoint of cost, availability, and plant injury.

In a separate laboratory experiment with three insecticides it was observed that paris green and copper cyanide were capable of causing considerable mortality purely by contact with the under surface of the body. Calcium arsenate was the least toxic of the three as a contact poison.

Field tests using calcium arsenate (3 to 5 pounds to 1000 square feet) gave satisfactory results —7-23-41.

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THE SERVICE ROSTER

Readers are requested not to forget to send to the Secretary of our Association or the Secretary of the Entomological Society of America the names and status of entomologists known to be in any branch of the armed services of the nation. A service roster, as complete as possible, is to be a feature of the New York Meetings.

Laboratory Tests of Organic Fumigants for Wireworms

RUSSELL S. LEHMAN, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*[1]

Experiments have been conducted for the purpose of determining the effectiveness of various liquid organic compounds as fumigants against wireworms, especially *Limonius canus* Lec. and *L. californicus* (Mann.), in soil. A total of 114 compounds have been tested, and the median lethal concentration has been determined for 57 of them. Many of the compounds have been used as fumigants against various insects by other investigators. Roark & Cotton (1930) used many of them against the rice weevil, *Sitophilus oryza* (L.).

[1] In cooperation with the Washington and Idaho Agricultural Experiment Stations. The work was performed at Walla Walla, Wash., under the direction of M. C. Lane, from 1937 to 1941. Mr. Lehman resigned Aug. 1, 1941.

MATERIALS, APPARATUS, and PROCEDURE—The wireworms were obtained from infested fields the preceding spring and summer by baiting with ground wheat. They were kept at 50° F. without food

Table 1.—Organic liquid compounds tested as fumigants against wireworms.

Compound	Median Lethal Concentration, Mgs. per Liter	Per Cent Killed by Fumigant	Concentration Mgs. per Liter
Acetaldehyde		None	781.0
Acetone		None	3168.0
Allyl bromide	4.19		
Allyl ethyl ether		33.3	805.0
Allyl formate	102.2		
Allyl iodide	5.54		
Allyl isothiocyanate	2.33		
Isoamyl alcohol		20.0	3276.0
tert-Amyl alcohol		11.1	243.0
Amyl capryllate		None	422.5
Allyl chloride	23.5		
Amyl formate	353.7		
Amyl propionate	245.5		
Anisic aldehyde		None	561.5
Anisic alcohol		None	554.5
Bornyl acetate		12.5	495.5
beta-Bromoethyl acetate	181.5		
beta-Bromoethyl ethyl ether	103.0		
Bromoform	234.5		
Bromostyrol	604.6		
Isobutyl acetate	375.4		
Isobutyl alcohol		20.0	3208.0
tert-Butyl alcohol		None	237.0
Isobutyraldehyde		None	158.8
Butyraldehyde	122.6		
Isobutyl benzoate	183.8		
tert-Butyl bromide		10.0	367.0
Butyl butyrate	194.7		
tert-Butyl chloride		None	252.0
Isobutyl formate		30.0	263.0
Isobutyl iodide	179.7		
sec-Butyl iodide	152.3		
n-Butyl mercaptan	175.6		
Isobutyl mercaptan	251.0		
Isobutyl valerate	118.7		
Carbon disulfide	68.2		
beta-Chloroethyl acetate	235.6		
Chloropicrin	4.76		
Cuminic aldehyde	195.6		
Dichloroethylene	293.2		
alpha, beta-Dichloroethyl ether		None	3522.0
beta, beta prime-Dichloroethyl ether	272.6		
Dimethyl *n*-propyl carbinol		None	1646.0
Dipentene		10.0	437.5
Epichlorohydrin	67.2		
Ethyl bromide	325.8		
Ethyl bromoacetate	155.6		
Ethyl isobutyrate	131.8		
Ethyl caproate	164.1		
Ethyl capryllate		10.0	439.0
Ethyl chloride		None	182.0
Ethyl iodide	129.5		
Ethyl mercaptan		100.0	252.0[1]
Ethyl phenylacetate	206.1		
Ethyl thiocyanate	297.8		
Ethyl isothiocyanate	3.16		
Ethylene bromide		None	219.0
Ethylene chloride	236.5		
Ethylene chlorohydrin	474.0		
Ethylene oxide		100	177.4[1]
Eucalyptol		80	450.5
Geranyl acetate		12.5	458.5
alpha-Ionone		None	465.0
beta-Ionone		11.1	472.0
Linalyl acetate		10.0	447.5
Mesityl oxide	206.8		
Methyl *n*-butyrate	199.8		
Methyl bromide	5.94		
Methyl bromoacetate	145.2		
Methyl isobutyl ketone		None	241.0
Methyl *n*-butyl ketone		40.0	250.0
Methyl caproate		44.4	307.4
Methyl capryllate	448.5		
Methyl cinnamate		None	521.0
Methyl disulfide	18.8		
Methyl ethyl ketone		None	1610.0
Methyl heptenone		80.0	430.0[1]
Methyl heptyl ketone		10.0	416.0
Methyl iodide	5.20		
Methyl thiocyanate		85.7	320.0[1]
Methylene iodide		88.9	333.0[1]
Octyl formate		60.0	436.0[1]
Paraldehyde		None	994.0
Lepidine		12.5	537.0
Phellandrene		None	421.5
Phenyl butyl ketone	504.9		
Phenyl ethyl acetate		12.5	513.0
Phenyl ethyl alcohol		12.5	512.0
Phenyl ethyl butyrate		None	496.0
Phenyl ethyl propionate		25.0	512.5
Phenyl ethyl valerate		12.5	504.0
Phenyl propyl alcohol		None	504.0
Phenyl propyl ketone		None	996.0
Pinene	439.0		
Isopropyl alcohol		None	3144.0
Propyl bromide		None	135.3
Propyl butyrate	197.8		
Isopropyl formate	264.9		
n-propyl iodide	198.5		
n-propyl mercaptan	152.8		
Propyl propionate	353.2		
Isopropyl thiocyanate	228.8		
Propyl valerate		75.0	444.5
Propylene chloride	263.2		
Propylene oxide	144.0		
Pyridine		None	3928.0
Rhodinol		12.5	450.0
Rhodinol acetate		None	442.5
Isosafrol		25.0	558.5
Terpineol		None	468.0
Terpinyl acetate		12.5	479.0
Tetrahydronaphthalene	388.4		
Trichloroethylene	168.6		

[1] Minimum concentration tested.

until a week to 10 days before use, at which time they were fed sterilized wheat and placed at a temperature of 68° F.

The fumigants tested were obtained from the manufacturers, and all were of C. P. grade. They were measured in a pipette, the lower concentrations being obtained by dissolving in ethyl alcohol. The small amounts of ethyl alcohol in themselves had no apparent effect on the wireworms.

In a 1-liter erlenmeyer flask 500 grams of Yakima silt loam soil of 22 per cent moisture content was placed together with 10 wireworms. A measured quantity of the fumigant was introduced into the flask, which was then closed with a rubber stopper and sealed with paraffin. The flask was rotated for exactly 1 minute to mix the fumigant thoroughly with the soil, and placed in a constant-temperature chamber, such as is described by Brindley & Richardson (1931), for 5 hours at 77° ±0.18° F.

At the end of this time the wireworms were removed from the flasks and examined. At this examination the wireworms were observed for signs of movement but were not handled any more than necessary. They were then transferred to fresh soil in salve tins and kept at 68° F. being examined again after 1, 3, 5, 7, and 10 days. Some were held a longer period if necessary. The wireworms were considered as having recovered from the effects of the fumigant if they were able to crawl, and none were considered dead unless they had decomposed.

The percentage of wireworms killed by the fumigant was calculated according to Abbott's formula (1925)

$$\frac{x-y}{x}100 = \text{per cent control}$$

where x = percentage living among the insects not exposed (checks) and y = percentage living among those exposed to a fumigant.

The median lethal concentration, or 50 per cent mortality point was calculated.

Approximately 8500 wireworms were employed in these experiments.

RESULTS.—The final results with the different fumigants are given in table 1. Many of the fumigants were retested several times to verify the results obtained. For compounds showing 100 per cent mortality the relative effectiveness is indicated by the median lethal concentration; for those not showing 100 per cent mortality, the percentage killed by the fumigant (per cent control) at the highest,

Table 2.—Median lethal concentrations of the various fumigants arranged in descending order of toxicity to wireworms.

FUMIGANT	MEDIAN LETHAL CONCENTRATION, MILLIGRAMS PER LITER
Allyl isothiocyanate	2.33
Ethyl isothiocyanate	3.16
Allyl bromide	4.19
Chloropicrin	4.76
Methyl iodide	5.20
Allyl iodide	5.54
Methyl bromide	5.94
Methyl disulfide	18.8
Allyl chloride	23.5
Epichlorohydrin	67.2
Carbon disulfide	68.2
Allyl formate	102.2
beta-Bromoethyl ethyl ether	103.0
Isobutyl valerate	118.7
Butyraldehyde	122.6
Ethyl iodide	129.5
Ethyl isobutyrate	131.8
Propylene oxide	144.0
Methyl bromoacetate	145.2
sec-Butyl iodide	152.3
n-Propyl mercaptan	152.8
Ethyl bromoacetate	155.6
Ethyl caproate	164.1
Trichloroethylene	168.6
Methyl formate	173.7
n-Butyl mercaptan	175.6
Isobutyl iodide	179.7
beta-Bromoethyl acetate	181.5
Isobutyl benzoate	183.8
Butyl butyrate	194.7
Cuminic aldehyde	195.6
Propyl butyrate	197.8
n-Propyl iodide	198.5
Methyl *n*-butyrate	199.8
Ethyl phenylacetate	206.1
Isopropyl thiocyanate	228.8
Bromoform	234.5
beta-Chloroethyl acetate	235.6
Ethylene chloride	236.5
Amyl propionate	245.5
Isobutyl mercaptan	251.0
Propylene chloride	263.2
Isopropyl formate	264.9
Mesityl oxide	266.8
beta, beta prime-Dichloroethyl ether	272.6
Dichloroethylene	295.2
Ethyl thiocyanate	297.8
Ethyl bromide	325.8
Propyl propionate	353.2
Amyl formate	353.7
Isobutyl acetate	375.4
Tetrahydronaphthalene	388.4
Pinene	439.0
Methyl capryllate	448.5
Ethylene chlorohydrin	474.0
Phenyl butyl ketone	504.9
Bromostyrol	604.6

or in a few cases the lowest, concentration tested is given.

In table 2 those fumigants for which the median lethal concentration was determined, as shown in table 1, have been arranged in their descending order of toxicity to wireworms.

Table 3.—Toxicities of certain compounds relative to the toxicity of carbon disulfide in soil and in air only.

FUMIGANT	RELATIVE TOXICITY In air	In soil
Carbon disulfide	1.0	1.0
Allyl isothiocyanate	192.9	29.3
Ethylene chlorohydrin	131.9	−7.0
Chloropicrin	45.9	14.3
Epichlorohydrin	39.8	1.02
β,β′-Dichloroethyl ether	35.0	−4.0
α, β-Dichloroethyl ether	9.2	−51.6[1]
Pyridine	5.3	−57.6[1]
Methyl formate	2.5	−2.5
Ethylene chloride	1.3	−3.5

[1] The figures given here are relative to the maximum concentration tested which gave no kill of wireworms. Therefore, the relative toxicity would be much less than shown.

DISCUSSION.—In this series of experiments allyl isothiocyanate proved to be the most toxic compound tested. When this compound was used in air alone in previous experiments by Lehman (1933), practically the same results were obtained. Of all fumigants tested in these experiments 10 showed median lethal concentrations lower than carbon disulfide and 46 higher.

Table 3 gives the relative toxicities of some of the compounds tested as compared with that of carbon disulfide, when used both in soil and in air alone. The data for the relative toxicity in air alone was taken from the previous publication (Lehman 1933).

Of the 9 compounds that were more toxic than carbon disulfide in air alone, only 3 were more toxic in the soil, and the relative toxicity was much less. The soil evidently absorbs much of the fumigant, making it less available to the insect. It is also true, as other (unpublished) tests have shown, that in the field diffusion plays an important part. Thus chloropicrin, which is 14.3 times as toxic as carbon disulfide in soil in the laboratory, is only twice as toxic in the field. Allyl isothiocyanate, which is 29.3 times as toxic in the laboratory, has about the same toxicity as carbon disulfide in the field. The greater toxicity of carbon disulfide to wireworms in the field is probably due to its ability to diffuse and its small loss by absorption in the soil.

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Japanese beetle certification requirements for fruits and vegetables were lifted for the season on September 9, 1942, as the active period of the beetle was apparently over. This order, issued as Circular B.E.P.Q. 524, by the Chief of the Bureau of Entomology and Plant Quarantine, released fruits and vegetables from certification requirements 5 weeks earlier than is provided in the regulations.

The use of ethylene dichloride emulsion dip as a treatment for balled or potted plants, for Japanese beetle larvae, was authorized by administrative instructions of the Chief of the Bureau of Entomology and Plant Quarantine, effective September 5, 1942, in supplement No. 6 to Circular B.E.P.Q. 499.

Toxicity of Paradichlorobenzene to Third-Instar Larvae of the Housefly[1]

H. C. Manis,[2] A. L. Dugas[2] and Irving Fox,[2] *Iowa State College, Ames, Iowa*

Despite the applicability of paradichlorobenzene in the control of insect pests of various kinds, little work has been done to ascertain its effectiveness as a housefly larvicide. Cook *et al.* (1915) tested numerous compounds in an attempt to obtain control of fly larvae in manure. Their results with paradichlorobenzene were variable and because of limited experimentation no definite conclusions were drawn concerning its effectiveness. In two sets of cage experiments they found that one-half pound of paradichlorobenzene in ten gallons of water applied to eight bushels of manure had a larvicidal effect of 50 per cent in one case and 93 per cent in the other, and that increasing the quantity of the larvicide to one pound of paradichlorobenzene in ten gallons of water gave 78 and 97 per cent kills in two tests. In a pit experiment involving one-half pound of paradichlorobenzene to eight bushels of manure an apparent larvicidal action of only 16 per cent was obtained. Gunther (1930) used 15 mm. larvae of *Musca vomitoria* to test a large number of compounds for their larvicidal effect. He found that a concentration of one-half per cent paradichlorobenzene gave no kill at 24 hours and 20 per cent kill at 48 hours. A concentration of 1 per cent resulted in 40 per cent kill in 24 hours and 100 per cent in 48 hours. Gorodetzkii & Sukhova (1936) used flower pots as experimental cages and introduced paradichlorobenzene crystals, at the rate of 0.05 gm. per sq. cm., into the center of each pot at a depth of 1 cm. and killed all the larvae and pupae of *Musca domestica* in dung and almost all in refuse. In some experiments, however, as many as 16 per cent of the larvae migrated. These authors also found that a 20 per cent solution of paradichlorobenzene applied to both dung and refuse at the rate of 0.25 cc. per sq. cm., killed, in 24 hours, all the larvae remaining in the flower pots. The solution proved to be a strong repellent, since 47.3 and 60.5 per cent respectively, migrated. In field tests they applied paradichlorobenzene at the rate of 30 oz. per sq. yd. and killed 95.7 per cent of the larvae and pupae in 2 days, but here again the experiments were apparently not an adequate test of the toxicity of this compound, since under these conditions, undoubtedly a high percentage of the larvae would be repelled.

It is the purpose of this paper to present experimental results to show the toxic action of a series of concentrations of paradichlorobenzene on the third instar larvae of the housefly, under laboratory conditions.

Procedure—Third instar larvae of the housefly, *Musca domestica* Linn., were used in these experiments. The larvae were grown at controlled temperature (30° C.) conditions and in a standard culture medium consisting of 13 grams of yeast, 100 grams of malt, 1475 grams of a bran-alfalfa meal mixture and 2100 grams of water. Larvae grown under the above conditions were selected at random and placed in a series of small, white, opaque glass jars; 10 larvae to each jar. Each jar contained 40 grams of the standard culture medium and was covered with cheese cloth.

Chemically pure paradichlorobenzene was finely ground and thoroughly mixed with the culture medium. The concentrations used were at the rate of 99.9, 149.8, 249.4, 497.5, 744.4, 990.1 and 1234.6 mg. of the larvicide per 100 grams of treated food. A total of 240 individuals were exposed to each concentration, except in the case of concentrations 497.5 and 990.1 mg., where only 180 individuals were used. One control jar containing 40 grams of untreated food accompanied each treated jar. All experiments were made at room temperature and were closed when all larvae had either died or pupated. All deformed pupae were considered as dead insects in the analysis of the data. Observations were made on all experi-

[1] The work was undertaken at the suggestion of Dr. C. H. Richardson of the Department of Zoology and Entomology, Iowa State College, to whom the authors are indebted for invaluable advice and assistance.

[2] Assistant Entomologist, Idaho Agricultural Experiment Station, Moscow, Idaho, Entomologist, Louisiana Agricultural Experiment Station, Baton Rouge, Louisiana, and Assistant Professor of Biology and Entomology, University of Puerto Rico, Rio Piedras, Puerto Rico, respectively.

ments at the end of 5 days. Further observations at a later date were necessary, however, to determine with accuracy the percentage of mortality.

A few practical tests were conducted in open and closed garbage pails, with paradichlorobenzene at concentrations corresponding to 497.5 and 1234.6 mg. per 100 grams of treated food.

RESULTS—The results of the experiments are given in table 1 and figure 1. The curve presented in the figure is a

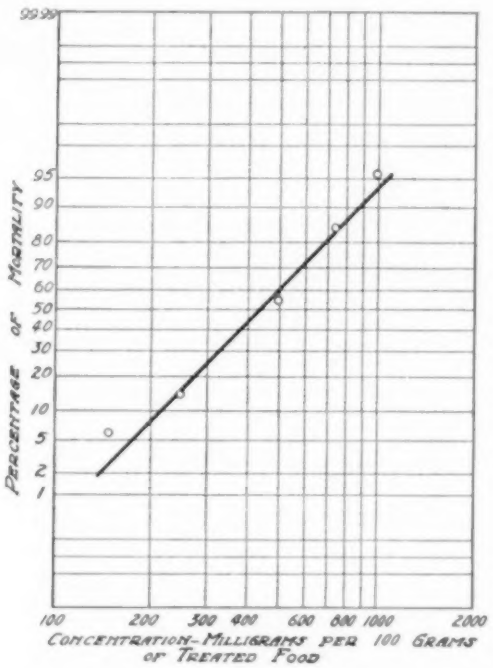

FIG. 1.—Results of tests with paradichlorobenzene against third instar larvae of the housefly, *Musca domestica* Linn.

regression line calculated according to the method of Bliss (1935). The chi-square test shows that the results are consistent with those found by random sampling of a homogeneous population. The calculated median lethal concentration of paradichlorobenzene for third instar larvae of the housefly, under the described conditions, is 430.5 mg. per 100 grams of treated food. Data for 0 and 100 per cent mortality were not used in the calculations. The results in the table show that there is a sharp rise in the toxicity between concentrations 249.4 and 497.5 mg. and that concentrations above 249.4 mg. are quite toxic to the larvae.

In the practical tests where concentrations corresponding to 497.5 and 1234.6 mg. were used 100 per cent mortality was observed in all cases, whether the garbage pail was closed or open. The 100 per cent mortality observed at the concentration corresponding to 497.5 mg. in these tests was probably due to the fact that the paradichlorobenzene was applied in a layer on top of the food and not mixed with the food as it was in the case of the laboratory tests. Such a high mortality percentage would probably not occur in open manure or refuse piles.

The toxicity of paradichlorobenzene in these experiments is apparently due to its combined action as a fumigant and a stomach poison. The larvae nearly always attempted to reach the surface of the food in the jar even at the lowest concentrations. At the higher concentrations the

Table 1.—Toxicity of paradichlorobenzene to third instar larvae of the housefly, *Musca domestica* Linn.

CONCENTRATION MG./100 GMS. TREATED FOOD	PERCENTAGE MORTALITY
99.9	0
149.8	5.22
249.4	14.72
497.5	54.86
744.4	84.91
990.1	95.43
1234.6	100.00

fecal deposits of the larvae were nearly always of a black viscous nature; and they adhered to the body surface adjacent to the anus and gradually hardened to form a black incrustation. This condition would seem to indicate some disturbance in the intestinal tract.

SUMMARY—Data are given on the toxicity of paradichlorobenzene to the third instar larvae of the housefly, *Musca domestica* Linn.

The results show that concentrations of the larvicide above 249.4 mg. per 100 grams of treated food are quite toxic to the larvae, and at a concentration of 1234.6 mg. per 100 grams of treated food 100 per cent mortality was obtained. The median lethal concentration of paradichlorobenzene was found to be 430.5 mg. per 100 grams of treated food.

Concentrations corresponding to 497.5 and 1234.6 mg. per 100 grams of treated

food resulted in 100 per cent mortality in open and closed garbage pails when applied as a layer over the top of the food.

The toxic action of paradichlorobenzene in these experiments is apparently due to its combined action as a fumigant and a stomach poison.—5-12-42.

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Toxicity of Acrylonitrile, Chloroacetonitrile, Ethylene Dichloride and Other Fumigants to the Confused Flour Beetle

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Toxicity tests of a number of chemicals, including acrylonitrile (Richardson & Casanges 1942), chloroacetonitrile, and ethylene dichloride, as fumigants were made in the laboratory against the confused flour beetle, *Tribolium confusum* Duv.

MATERIALS AND METHODS.—The insects were reared on finely ground whole-wheat flour to which was added yeast and milk powder (8:1:1 by weight). Beetles 30 to 60 days old usually were used. The chemicals tested are listed in table 1. They were of C. P. quality except as noted.

All chemicals except methyl bromide were tested in a 5- or 6-liter glass flask (Fig. 1). The flask was first swept out with air at 50 per cent relative humidity and near 25° C. The pressure in the flask was lowered by suction to approximately 650 to 600 mm. of mercury, absolute pressure. Ethylene oxide was measured into the flask by a gas burette. The other chemicals were measured by means of a pipette graduated to 0.001 ml. Quantities as low as 0.01 ml. or less of liquids with a vapor pressure as high as that of carbon disulfide were accurately and conveniently measured by use of a 0.5-ml. hypodermic syringe lubricated with stopcock grease and attached to the pipette by a short piece of heavy walled rubber tubing (Fig. 1, C).[1] This apparatus could be easily moved about under the laboratory hood without loss of liquid. Immediately after the chemical was measured into the funnel (Fig. 1, B), the stopcock was turned and the chemical was drawn into the flask, where it evaporated at the lower pressure. When very small quantities of the more volatile chemicals were used, the stopcock was turned on slightly during measurement so that the chemical was drawn into the flask with a current of air as soon as it left the pipette. When evaporation was complete, air was drawn in to normal atmospheric pressure. The celluloid-covered rubber stopper with glass stopcock was then removed and quickly replaced by a ground-glass stopper from which a copper screen cage containing 50 to 75 insects was suspended (Fig. 1, right). Undoubtedly there was a small loss of gas-air mixture, but tests with ethylene dichloride indicated that mortality was just as high by this method as by the technique used by Strand (1930) and Shepard *et al.* (1937). This procedure (1) eliminated any possibility of droplets of the chemicals, particularly those of lower vapor pressure, making direct contact with the insects before complete evaporation and (2) exposed the insects to the full concentration of the insecticide at the beginning of fumigation and kept them at normal atmospheric pressure at all times. The number of stopcocks and other glassware needed for introduction of the chemical was reduced to a minimum, since one set was sufficient for all tests. The

[1] This method has been used recently by the senior writer for the measurement of other insecticidal liquids and found very convenient.

results were practically the same whether a celluloid-covered rubber stopper or a ground-glass stopper was used on the flask. The type of stopper may be of importance, however, when low concentrations of some chemicals are used. Good gas distribution was obtained simply from the air currents that swept in when the flask was brought back to normal atmospheric pressure, as indicated by the mortality of insects placed in the upper and lower portions of the flask.

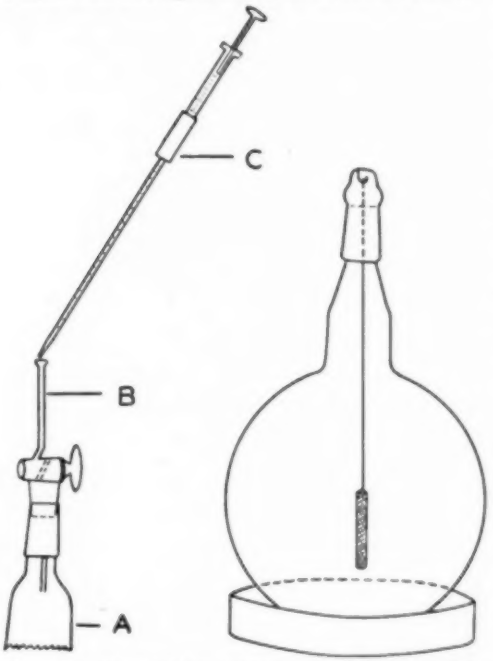

FIG. 1.—Fumigation apparatus. Left—Arrangement during measurement of chemicals into flask. A. Top of flask; B. Stopcock with attached funnel; C. Micropipette with syringe. Right—Arrangement during fumigation.

The insects were exposed to the fumigant for 5 hours at 25±0.5° C. Usually 6 to 8 tests, using various concentrations, were made of most chemicals. Fifty to 75 insects were used in each test. After fumigation the beetles were placed with a small quantity of flour in open vials[2] ¾ inch by 2 inches and held at 25° C. and approximately 60 to 70 per cent relative humidity. Examinations were made at 4, 10, 20, and in some tests 40 days after fumigation.

Methyl bromide was tested in a 7.7-cubic-foot steel cylinder at 2½ hour exposures.

POST-FUMIGATION EFFECTS.—Mortality counts were made over a period of 20 days or more after fumigation to determine the most suitable time to make final observations on efficiency. Some of the results are shown in figure 2.

With most of the chemicals there was little change in mortality over the period. The effect of ethylene dichloride was exceptional in that mortality gradually increased. Shepard & Buzicky (1939) found that ethylene dichloride produced a delayed mortality over the first 10 days after fumigation, but the present study shows that this effect continued beyond 10 days, 40 to 60 per cent of the beetles sometimes being killed between the tenth and twentieth days. There were only slight increases in mortality between the twentieth and fortieth days. The mixture of ethylene dichloride with carbon tetrachloride (Cotton & Roark 1927) was found to have a similar latent effect. Carbon tetrachloride alone appeared to have no latent effect in a preliminary test at the concentration used in the mixture.

COMPARATIVE TOXICITY OF THE FUMIGANTS.—Mortality data taken 20 to 21 days after fumigation were plotted on logarithmic probability paper, and toxicity curves were fitted carefully by hand. The approximate concentrations by weight to kill 50 and 95 per cent of the insects are given in table 1. Chemicals tested in 1939 and in 1941 gave similar results for the 2 years.

The most toxic chemicals were chloroacetonitrile and acrylonitrile. Chloroacetonitrile appeared slightly more toxic, but it had the disadvantage of being less volatile. Both chemicals gave toxicity values almost as high as those reported for hydrocyanic acid by Shepard *et al.* 1937. They had a slightly delayed killing action. For example, the insects appeared either normal or only slightly affected at the end of a 5-hour exposure to a killing dosage (3 mg. per liter), but all were dead 6 hours later. On the other hand, hydrocyanic acid has no latent effect on beetles

[2] Open vials were used because studies have indicated that toxic concentrations of gases are likely to be formed when this beetle is kept for short periods in small, tight containers. When 70 to 75 beetles were held in a 125-ml. flask with a ground glass stopper, for 5 hours at 25° C. without the addition of air or fumigant, considerable mortality took place. When cork stoppers were used in place of ground-glass stoppers, there was little or no mortality. When an airflow of 6 liters per hour was maintained through the flask, or when 70 to 75 insects were kept in a 5-6-liter flask, no mortality occurred. It is not certain whether these effects are due to gas given off by the beetle (Roth *et al.* 1941), to the mixture with carbon dioxide, or to other factors.

Table 1.—Comparative toxicity of various chemicals to *Tribolium confusum* in 5-hour exposures at 25° C. Static fumigations. Mortality data taken 20 to 21 days after fumigation.

Chemical	Approximate Concentration to Give—[2]	
	50 Per Cent Mortality	95 Per Cent Mortality
	Mg. per Liter	*Mg. per Liter*
Chloroacetonitrile[1] (CH_2ClCN)	<2	<3
Acrylonitrile[1] ($CH_2:CHCN$)	>2	<3
Methyl bromide[1] (CH_3Br)	8[3]	11[3]
1,1-Dichloro-1-nitropropane[1] ($CH_3CH_2CCl_2NO_2$)	8	11
1,1-Dichloro-1-nitroethane[1] ($CH_3CCl_2NO_2$)	9	12
Ethylene dichloride (CH_2ClCH_2Cl)	6	12
Ethylene dichloride-carbon tetrachloride mixture (3:1 by volume) (CH_2ClCH_2Cl with CCl_4)	9	14
Methylallyl chloride (3-chloro-2-methyl propene) ($CH_2:C(CH_3)CH_2Cl$)	12	19
Methyl allyl bromide (3-bromo-2-methyl propene) ($CH_2:C(CH_3)CH_2Br$)	14	—
Ethylene oxide ($(CH_2)_2O$)	<20	<25
Carbon disulfide (CS_2)	56	100
Ethyl bromide (CH_3CH_2Br)	>150	<200

[1] Technical products obtained commercially.
[2] < = less than, > = greater than.
[3] Estimated from 2½-hour exposure.

that show life at the end of fumigation (Shepard & Buzicky 1939). Acrylonitrile and chloroacetonitrile had no pronounced delayed killing action after the fourth day, such as shown by ethylene dichloride (Fig. 2). Acrylonitrile (propenenitrile) is a colorless liquid with a boiling point of 78 to 79° C., near that of ethylene dichloride, and is used in the synthesis of artificial rubber. Both nitriles appear worth further investigation as fumigants (Peters 1940). More recent studies by the senior writer have shown both chemicals to be very toxic to the bedbug, *Cimex lectularius* L. Dudley & Neal (1942) have recently reported that the toxic action of acrylonitrile to warm-blooded animals is probably due to the cleavage of the molecule producing hydrogen cyanide. Guinea pigs showed a marked resistance, but dogs were very susceptible.

Two chemicals closely related to chloropicrin namely, 1,1-dichloro-1-nitroethane (O'Kane & Smith 1941) and 1,1-dichloro-1-nitropropane, appeared to be next in toxicity. The latter seemed slightly more toxic, but it had the disadvantage of being less volatile. Methyl bromide, as tested in the steel cylinder, appeared to have about the same toxicity as these chemicals. The approximate concentrations to produce 50 and 95 per cent mortality in 2½-hour exposures were 16 and 22 mg. per liter, respectively. Assuming that gas concentration and exposure time were inversely proportional, as indicated by the work of Hamilton (1941), the respective concentrations for a 5-hour exposure would be about 8 and 11 mg. per liter. Methyl allyl chloride (Briejèr 1938, 1939; Peters 1939) and methyl allyl bromide were less toxic than the chemicals previously mentioned. These closely related chemicals appeared to differ little in toxicity, but the mortality data for the latter were less consistent.[3] Ethylene oxide was close to these insecticides in the toxicity scale. Carbon disulfide was much less toxic than the other chemicals, followed by ethyl bromide. The toxicity values for the last two chemicals were fairly similar to those reported by Niefert *et al.* (1925).

Because of its great latent effect, ethylene dichloride had a toxicity value near those of methyl bromide and 1,1-dichloro-1-nitroethane. If it has such a latent effect on other insects, this may help to explain its wide use and apparently good efficiency in practical fumigation. The addition of carbon tetrachloride to ethylene dichloride (1:3 by volume or 2:3 by weight) to produce a noninflammable mixture seemed to increase the insecticidal action little, as judged by 20-day counts. (See also

[3] Silverman & Abreu (1938) report methyl allyl chloride to be potentially dangerous to persons working with it in factories and laboratories, but this is true of most fumigants.

Shepard & Lindgren 1934.) In a series of five paired tests ethylene dichloride at concentrations of 7 to 13.9 mg. per liter produced an average mortality of 85.38 per cent (range 65.8 to 98.6 per cent), whereas the ethylene dichloride-carbon tetrachloride mixture at concentrations with the same weight of ethylene dichloride per liter produced an average mortality of 85.72 per cent (range 72.7 to 97.2 per cent). The average difference was 0.34 per cent, with a standard error of 2.05, indicating no significant difference.

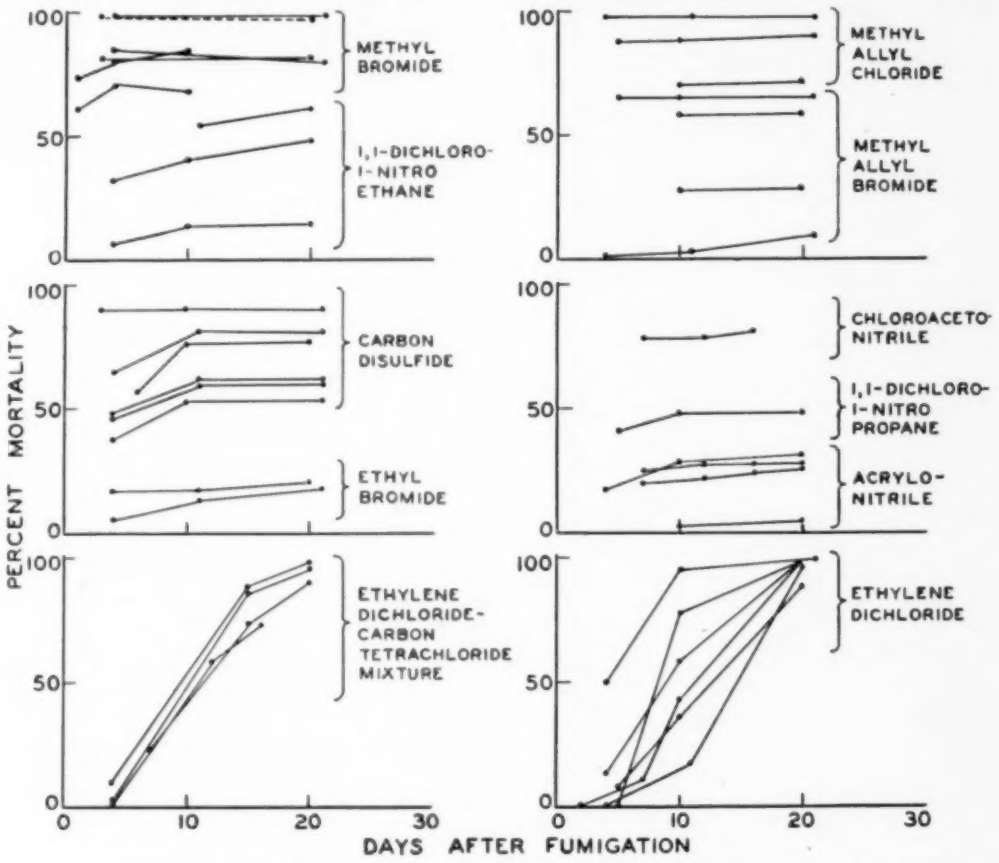

FIG. 2.—Apparent mortality of *Tribolium confusum* over a period of 2 to 20 or 21 days after fumigation with various chemicals.

The delayed killing action of ethylene dichloride brought up the question of whether the beetles laid viable eggs before they died. A preliminary test indicated that a few viable eggs might be laid when beetles are exposed to a concentration of 20 mg. per liter and that to prevent egg laying the concentration should be increased. Whether concentrations as great as 45 to 73 mg., as used by Strand (1930), Shepard *et al.* 1937, and Shepard & Buzicky 1939, are necessary is not known.

The high toxicity of some of these chemicals apparently was not due to the use of a weak stock of insects. Carbon disulfide, methyl bromide, and ethylene oxide gave results not far different from those reported by Shepard *et al.* (1937), who made mortality counts 40 to 48 hours after fumigation and counted moribund beetles as alive. In addition, the results with 1,1-dichloro-1-nitroethane indicated the insects to be of greater resistance than those used by O'Kane & Smith (1941).

SUMMARY.—Laboratory tests on the toxicity of certain chemicals as fumigants were made against the confused flour beetle, *Tribolium confusum* Duv., in 5-hour exposures at 25° C. Small volumes of chemicals as volatile as carbon disulfide

were conveniently measured by use of a small hypodermic syringe attached to a micropipette.

Acrylonitrile and chloroacetonitrile were the most toxic chemicals and appear worth further study as fumigants. They were also very toxic to the bedbug, *Cimex lectularius* L. Other chemicals tested are listed by groups approximately in the order of decreasing toxicity, as follows: (1) Methyl bromide, 1,1-dichloro-1-nitropropane, and 1,1-dichloro-1-nitroethane; (2) methyl allyl chloride, methyl allyl bromide, and ethylene oxide; (3) carbon disulfide; and (4) ethyl bromide.

Ethylene dichloride was found to have a delayed killing action, which increased mortality considerably over a period of about 20 days after fumigation. A noninflammable mixture with carbon tetrachloride (3:1 by volume) also showed a latent effect, but the carbon tetrachloride added little or nothing to toxicity. Judging only from the mortality produced after 20 days, ethylene dichloride is not far below methyl bromide in the toxicity scale. However, beetles fumigated with these low concentrations of ethylene dichloride may lay viable eggs before death, and the dosages must be increased to prevent egg laying.—6-15-42.

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DR. GOBEIL BECOMES MANAGER OF THE QUEBEC FORESTRY ASSOCIATION

Dr. A. R. Gobeil, who has been for some years the Director of the Entomological service of the Ministère des Terres et Forêts of the Province of Quebec, Canada, has resigned from that position to become manager of the Quebec Forestry Association, according to information furnished by M. Gérard Paquet, of the Entomological Service.

The Compound, 4,6-Dinitro-o-Cresol as a Cockroach Poison

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In recent years a number of nitrophenols have been tested by entomologists to determine their insecticidal potentialities. Promising results have been obtained with several of these compounds, one of the outstanding being 4,6-dinitro-o-cresol.[1]

The discovery that 4,6-dinitro-o-cresol is toxic to insects is not a recent development. According to Kagy & Richardson (1936) the potassium salt of this chemical was used in a proprietary insecticide named *Antinonine* as early as 1892. Tattersfield *et al.* (1925) reported 100 per cent control with this compound when used in tests against adults of *Aphis rumicis* L. and eggs of *Selenia tetralunaria*. Since then other workers have reported it to be highly toxic to additional species of insects. Space does not permit a complete review of the literature, as 29 papers were examined which reported excellent kills with this chemical against insects. The following lists, however, shows the wide range of insects that have been found susceptible. It has been highly toxic in winter washes against the eggs of several species of aphids, the apple sucker, *Psylla* sp. (Jary 1928), leaf bugs (Miles 1929), tortricids (Hodson & Beaumont 1928), and the winter moth (Gimingham & Tattersfield 1928). It has also been found effective against bees (Ginsburg 1928), larvae of the codling moth, *Carpocapsa pomonella* (L.), (MacAllister & Van Leeuwen 1930), the pomace fly, *Drosophila ampelophila* Loew, (Patterson 1934), a geometrid larvae (Kiefernspanner) (Schwerdtfeger & Stahl 1937), *Anthonomus pomorum* L. (Thiem 1938b), the cherry fruitfly, *Rhagoletis cerasi* L. (Thiem 1938a), cockchafers and their larvae (Blunck *et al.* 1939), adult leaf bugs (Tischler 1939), and larvae of the screwworm, *Cochliomyia americana* C. & P. (Bushland 1940). In a number of cases, however, the compound was toxic to foliage.

In preliminary tests, 4,6-dinitro-o-cresol was found to be highly toxic when applied to the American cockroach, *Periplaneta americana* (L.), in battery jars. Additional tests have now been made against this species (1) to compare the relative toxicity of 4,6-dinitro-o-cresol, pyrethrum, and sodium fluoride when mixed with dust diluents at various concentrations, (2) to determine the effect of exposure on the toxicity of 4,6-dinitro-o-cresol, and (3) to study the effect of applying 4,6-dinitro-o-cresol as a contact insecticide.

MATERIALS.—The roaches were reared in the laboratory in glass-lined wooden boxes approximately 15 inches square and 6 inches deep. No cover was used on the boxes, the glass sides being coated with vaseline to prevent escape of the roaches. The insects were fed commercial dog-food biscuits and water.

The 4,6-dinitro-o-cresol sample was a yellow powder of high quality, having a melting point of 85–86° C. The sodium fluoride sample was a fine white powder containing 90 to 95 per cent of active ingredients. The pyrethrum sample was a brown powder ground to permit 42 per cent to pass through a 200-mesh sieve and, according to a recent analysis, contained 0.33 per cent of pyrethrin I and 0.38 per cent of pyrethrin II. All dilutions were made by grinding weighed portions of chemical and a diluent in a mortar until the two were thoroughly mixed.

EXPERIMENTAL TEMPERATURES.—The experiments were conducted in the early spring months at room temperature in a building that was heated in the daytime but not at night. During the daylight hours the temperature was maintained between 70° and 80° F., but it occasionally dropped as much as 20 degrees for short periods between midnight and 8 a.m.

COMPARATIVE TOXICITY TESTS.—In preliminary tests a mortality of 100 per cent was always obtained with undiluted 4,6-dinitro-o-cresol. A series of tests was therefore made to study the effect of dilution on the toxicity of the compound. At the same time similar tests were run with pyrethrum and sodium fluoride to permit a comparison of the relative toxicities of the three compounds when used under the same conditions. Talc was used as the

[1] This chemical is also called 3,5-dinitro-o-cresol. In the United States the hydroxyl group is assigned position 1 in the ring, whereas in Europe the methyl group is assigned this position. (It is also called 4,6-dinitro-2-methylphenol in some terminologies, according to the reviewer of this paper.—Ed.)

diluent, and the tests were replicated 5 times.

The roaches were confined on sheets of waxed paper in pens 14 inches square and 5 inches high. The barriers for these pens were formed by bending 28-inch strips of 28-gage galvanized metal at right angles and soldering the ends together to form squares. The metal was greased on the inside with vaseline. One gram of the material to be tested was dusted from a pepper shaker to form a band approximately 1 inch wide across the middle of each pen from side to side, and 10 adult roaches were placed in the pen. This method of applying the chemical permitted the insects to avoid contact with it if it was repellent to them. Since roaches frequently have been kept alive in the laboratory as long as 3 weeks without being fed, no food was supplied during the short testing periods employed in this work. Water was eliminated to prevent the insects from getting their bodies wet and picking up excessive amounts of the chemical. Mortality counts were made at intervals of 3, 6, 12, 24, 48, and 72 hours.

The results, which are presented in table 1, show that 4,6-dinitro-o-cresol was very toxic to adult roaches at concentrations as low as 5 per cent. However, its effectiveness decreased rapidly when lower concentrations were used, although a 1 per cent concentration killed 44 per cent of the insects in 72 hours. The compound was more toxic than either sodium fluoride or pyrethrum, causing higher mortalities in 72 hours at a concentration of 5 per cent than pyrethrum at the same concentration or sodium fluoride at 50 per cent. Undiluted sodium fluoride was the only concentration of this chemical that produced a kill of 100 per cent within 72 hours, whereas total mortality was obtained with pyrethrum at concentrations of 10, 25, and 50 per cent and with 4,6-dinitro-o-cresol at all concentrations down to 10 per cent. 4,6-Dinitro-o-cresol was still fairly toxic at 1 per cent, whereas pyrethrum was ineffective below 5 per cent, and sodium fluoride was only slightly effective below 25 per cent. Extending the duration of the tests probably would have caused additional mortality in some cases.

The outstanding characteristic of 4,6-dinitro-o-cresol observed in these tests was the rapidity with which it killed. Very little mortality was recorded with pyrethrum or sodium fluoride until the 12-hour count was made, whereas kills of 90 to 100 per cent were obtained in 3 hours with 4,6-dinitro-o-cresol at the higher concentrations. A 50 per cent kill in 3 hours occurred at concentrations as low as 5 per cent. The compound at a concentration of 10 per cent killed more insects in 6 hours than did sodium fluoride at 50 per cent in 72 hours, and at 5 per cent killed about as many in 12 hours as did undiluted sodium fluoride in 24 hours. It was more effective at 5 per cent in 12 hours than was pyrethrum at 10 per cent in 24 hours.

Table 1.—Toxicity of 4,6-dinitro-o-cresol, pyrethrum, and sodium flucride when used at various concentrations against adults of the American cockroach.

Per Cent of Compound in Talc	Per Cent Kill in—					
	3 Hours	6 Hours	12 Hours	24 Hours	48 Hours	72 Hours
4,6-Dinitro-o-cresol:						
100 (no talc)	100	100	100	100	100	100
50	98	100	100	100	100	100
25	90	100	100	100	100	100
10	62	92	98	100	100	100
5	50	74	90	94	96	96
3	12	22	28	40	54	60
1	4	10	16	26	36	44
Pyrethrum:						
100 (no talc)	0	0	2	34	94	94
50	4	12	70	100	100	100
25	0	22	86	100	100	100
10	0	0	26	78	98	100
5	0	2	20	52	64	64
3	0	0	0	0	0	0
1	0	0	0	0	0	0
Sodium fluoride:						
100 (no talc)	0	8	46	92	100	100
50	0	0	8	44	72	88
25	0	0	2	22	62	82
10	0	0	0	0	4	18
5	0	0	0	0	0	10
3	0	0	0	0	0	10
Check (unpoisoned talc)	0	0	0	0	0	0

Since roaches were not considered dead until all movement ceased the results in table 1 do not give an entirely accurate picture of the efficiency of the pyrethrum sample because most of the insects exposed to this insecticide lay prostrate on their backs for several hours before they died. They usually ran wildly around the pen within 5 minutes of coming in contact with the pyrethrum before falling on their backs. At concentrations above 25 per cent all the roaches were on their backs within 30 minutes. All the insects treated with the 25- and 10-per cent dusts were prostrated within 25 to 90 minutes while

46 per cent of those used in the tests at 5 per cent were on their backs at the end of 3 hours. The concentrations below 5 per cent did not seriously disturb the roaches. In contrast to pyrethrum, 4,6-dinitro-o-cresol had a lethargic effect on the roaches.

DILUENT TESTS.—Since it was possible that other materials might be superior to talc as carriers for 4,6-dinitro-o-cresol, seven commonly used diluents were employed to determine their relative value when used with this compound. The materials used were bentonite, hydrated lime, redwood bark flour, soybean flour, sulfur, talc, and wheat flour. Each was a finely ground powder that could be readily mixed with the 4,6-dinitro-o-cresol by grinding in a mortar. All tests were made in the previously described pens at an insecticide concentration of 5 per cent and were replicated five times.

In the tests reported in table 2 there appears to be little difference in the results obtained with the compound when diluted with redwood bark flour, soybean flour, talc, and wheat flour. Hydrated lime and sulfur seem to be slightly inferior, chiefly because of the low mortality during the early hours of the experiment. Bentonite was definitely inferior to the other materials, for it consistently retarded the action of the compound throughout the 72 hours.

Table 2.—Toxicity of 4,6-dinitro-o-cresol at a 5 per cent concentration when mixed with various diluents.

Diluent	Per Cent Mortality in—					
	Hours					
	3	6	12	24	48	72
Bentonite	0	0	2	28	42	50
Hydrated lime	0	8	16	24	68	82
Redwood bark flour	32	54	76	80	84	90
Soybean flour	26	38	46	82	84	84
Sulfur	8	30	56	66	74	78
Talc	32	58	72	82	86	88
Wheat flour	26	48	54	70	84	88
Check (untreated)	0	0	0	2	2	2

Not all these dusts were easily dispensed from the pepper shaker. Talc, sulfur, redwood bark flour, and hydrated lime caused practically no stoppage, but wheat flour and bentonite were more difficult to apply. However, the greatest difficulty was encountered with soybean flour, for it conglomerated and stuck in the top of the shaker, clogging the holes.

EXPOSURE TEST.—Some organic insecticides lose their effectiveness after being exposed to air or light for short periods. Since roaches often do not come in contact with poisons intended for them until several days after the material has been applied, it is desirable that an insecticide for this pest retain its effectiveness for a number of days. Consequently, pens that had been dusted with 4,6-dinitro-o-cresol were exposed for 7 days before roaches were added. Other tests were made with freshly applied 4,6-dinitro-o-cresol as a check. A 10-per cent dust in talc was used, and each test was replicated 5 times.

Mortalities after 6 hours of 100 per cent with the exposed dusts and 90 per cent with the freshly applied material showed that 4,6-dinitro-o-cresol does not rapidly lose its toxicity.

CONTACT TESTS.—It is often helpful in planning methods of application to know the mode of toxic action of an insecticide. As noted before, Tattersfield *et al.* (1925) and others found 4,6-dinitro-o-cresol effective as a contact poison for insect eggs, but so far no investigators have reported it as an effective stomach poison. However, Kagy (1936) tested a number of related nitrophenols on last-instar corn ear worms, armyworms, and cabbage worms by the leaf sandwich method and reported them to be more toxic than acid lead arsenate.

4,6-Dinitro-o-cresol was tested as a contact insecticide against the American cockroach by comparing the time required to kill 100 per cent of the roaches with the time required when sodium fluoride and pyrethrum were used. The technique was similar to that described by Munger & Siegler (1937). Rubber collars were placed around the necks of 10 last instars by inserting the heads through small holes in pieces of toy balloons. By regulating the tension on the rubber the size of the opening was adjusted to allow free movement of the head without permitting its withdrawal. The insects were then placed in small glass tubes (five-eighths inch in diameter and 2 inches long) and the rubber collars stretched over one end and fastened with a rubber band. After 1 hour, during which time the insects

were watched for signs of injury, the insecticide diluted to 25 per cent with talc was dusted into the tubes through the open end. In this way the chemical was applied to the bodies of the insects without danger of its reaching the mouth parts. The tubes were maintained in a horizontal position, and the insects examined at short intervals for mortality. Food and water were not supplied during the testing period.

4,6-Dinitro-o-cresol was found to be an excellent contact insecticide; all 10 of the insects treated with it died within 2 hours. Sodium fluoride and pyrethrum were also effective, but they required a much longer time to kill. After 12 hours the pyrethrum sample had killed 40 per cent of the insects, but all those dusted with sodium fluoride were still alive. At the end of 16 hours both compounds had caused a mortality of 100 per cent. Undusted roaches used as checks were still alive when their collars were removed 1 week after the start of the tests, but others dusted with talc survived only 48 to 72 hours.

TESTS WITH A PRACTICAL-GRADE SAMPLE.—The 200-gram sample of high-grade 4,6-dinitro-o-cresol used in the tests just described cost $3.20. However, a practical-grade material was available commercially in 1941 at 35 cents per pound when purchased in large quantities. This product at concentrations of 5 and 10 per cent in talc was tested against adult roaches to determine its efficiency as a substitute for the higher priced chemical. These tests were made in the galvanized-metal pens and were replicated five times.

This sample also was very toxic to the roaches. In fact, the results obtained in the first 3 hours were slightly higher at both concentrations than for corresponding concentrations of the high-grade sample. Mortalities of 84 per cent with the 10 per cent dust and of 58 per cent with the 5 per cent dust were obtained in that time. The remaining results with the 10 per cent dusts compared favorably with those presented in table 1 for 10 per cent 4,6-dinitro-o-cresol, a mortality of 96 per cent resulting in 6 hours. The 5 per cent dust was less toxic after 12, 24, and 48 hours then the same concentration of the high-grade product but produced a kill of 92 per cent in 72 hours.

If this product should prove to be as effective against roaches under practical conditions as it did in the laboratory, the ingredients for a highly toxic roach poison composed of 10 per cent of 4,6-dinitro-o-cresol and 90 per cent of talc could be purchased in large quantities for approximately 5 cents per pound.

POSSIBLE LIMITATIONS IN PRACTICAL USE.—While the results of these toxicity tests show 4,6-dinitro-o-cresol to be highly toxic as an insecticide for American roaches, the compound has certain characteristics that may limit its use as a control for this pest. One objection to some of the roach poisons in common use today is the danger of household pets being poisoned by them. The substitution of 4,6-dinitro-o-cresol probably will not eliminate this danger, for Meyer (1934) has reported the compound toxic to animals at dosages of 7 to 10 milligrams per kilogram of body weight. In dusting the chemical, the author occasionally experienced a nasal irritation that was usually followed several hours later by pains through the chest.

4,6-Dinitro-o-cresol might easily cause yellow stains on floors and furniture. A 25 per cent dust that was applied to sections of two pine floors painted with a dark varnish and a light gray paint, respectively, did not stain during a 2-day period, but when allowed to remain as long as a month it discolored them badly. However, when the chemical was exposed on large sheets of waxed paper, instead of in direct contact with the floor, no staining of the floor occurred with 4 months.

SUMMARY.—In toxicity tests against the American cockroach, *Periplaneta americana* (L.), 4,6-dinitro-o-cresol was found to be more toxic and to kill more rapidly than either sodium fluoride or pyrethrum within a 3-day period, being more effective at a 5 per cent concentration than pyrethrum at 5 per cent or sodium fluoride at 50 per cent. Exposure to the air in a room for 7 days did not destroy the toxicity of a 10 per cent dust. In tests designed to eliminate the possibility of ingestion the compound was highly effective as a contact insecticide Of seven materials tested as diluents, talc and redwood bark flour were found to be the most effective. The ingredients for a highly toxic roach poison containing this chemical could be purchased in large quantities in 1941 for approximately 5

cents per pound. Two characteristics that may limit its use as a control for roaches are its toxicity to animals and its tendency to stain.—4-11-42.

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IXODES DENTATUS FROM IOWA

Since the publication in 1942 of the paper "Ticks Collected on the Tama (Iowa) Indian Reservation with Notes on other Species" by the authors, another species of tick previously unreported from Iowa has been collected. An engorged female of *Ixodes dentatus* Maix was taken from the cottontail, *Sylvilagus floridanus mearnsii*, near Ames, Iowa, on June 17, 1942 by the authors.

Little is known as to the natural range of this tick. The type specimen, a female, is in the Maix Collection and was taken from a rabbit in Maryland. C. N. Smith, U. S. Bureau of Entomology and Plant Quarantine, reported in 1940 that it is quite common on the cottontail rabbits on the island of Martha's Vineyard in Massachusetts. He described the male nymphs and larvae. Rabbits and hares are the principal host animals.

The tick was determined by Dr. R. A. Cooley, U. S. Public Health Service, Rocky Mountain Laboratory, Hamilton, Montana. It was the only specimen of *Ixodes dentatus* that the authors were able to obtain from considerable collecting in central Iowa.—9-10-42.

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Methyl Bromide Fumigation to Control Oriental Fruit Moth on Dormant Nursery Stock

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The oriental fruit moth, *Grapholitha molesta* (Busck), was probably introduced from Japan about 1913. Since that time it has spread nearly to the limits of commercial peach culture in the eastern half of the United States. Despite the widespread occurrence of hosts, the insect is not disseminated throughout the western states. It is not known to be present in Arizona, California, Colorado, Idaho, Nevada, Oregon, Utah, and Washington, and these states have promulgated quarantines against the entry of all species and varieties of nursery stock, including the ornamental forms of almond, apple, apricot, cherry, chokecherry, hawthorn, nectarine, peach, pear, plum, and quince originating in the infested territory, to prevent the entrance of this pest. The study here reported was undertaken to develop a method for quickly and economically disinfesting dormant nursery stock grown in infested areas so that it might be shipped without danger of carrying the pest with it. The experimental work was done intermittently during the period 1938 to 40.

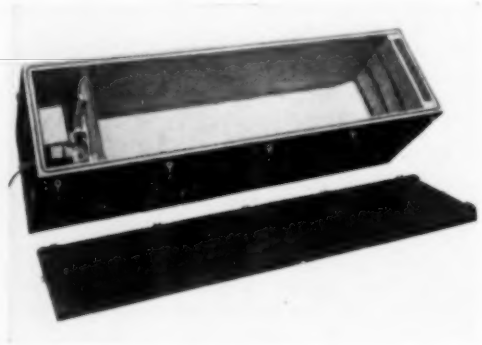

Fig. 1.—Portable fumigator used for treating dormant nursery stock with methyl bromide.

In summer the larva infests the pulp of fleshy fruits and the tips of tender twigs of several species of cultivated trees and shrubs. The insect hibernates as a larva within the cocoon, which is frequently located beneath flakes of loose bark or in crevices of healed wounds. The hibernating larva transforms to the pupal stage in late winter or early spring. Cocoons of hibernating fruit moths are found on nursery stock throughout the dormant season.

The danger of dissemination on nursery stock is dependent to a considerable extent on the frequency of occurrence of cocoons on such material. Peterson & Haeussler (1926) held that the rapid spread of the insect in the eastern states was due chiefly to shipment of infested fruits and nursery trees. It seems doubtful, however, that heavy infestations would be found on nursery stock owing to the smoothness of the bark and the lack of crevices. The percentage of larvae overwintering on the tree in comparison with that in other locations depends among other factors on weather conditions, roughness of bark, debris on the ground, and the time the fruit ripens. Steiner (1932), in the Midwest, found that the percentage on the peach tree ranged from 18.6 to 100. Stearns (1927), in New Jersey, reported finding 25 per cent cocooned on the trees and 75 per cent elsewhere. Snapp & Swingle (1929) pointed out that some larvae cocooned in hollowed-out twigs. The writers have observed that the larvae may remove the pith from severed ends of twigs to enter for cocooning and that they cocoon readily on the smooth bark of twigs when confined without material offering more suitable locations, and occasionally under natural conditions in the exit holes of the shot-hole borer, *Scolytus rugolosus* Ratz.

Methods and Materials.—Two series of fumigation experiments were carried out. The first was a series of laboratory tests designed to determine which of several common gases showed the greatest toxicity to the insect. Then, after selection of the fumigant, which was methyl bromide, a series of fumigations, called commercial tests, was conducted.

In the laboratory tests 5-gallon glass bottles were used as fumigation chambers. Hibernating larvae were suspended in the center of the bottles, and the fumigant was introduced from a graduated pipette. A constant temperature of 70° F. was maintained.

In the commercial tests with methyl bromide the fumigation equipment consisted of a rectangular-shaped metal-lined chamber (Fig. 1). having a capacity of 46.5 cubic feet. The seams were made tight by soldering, and the walls were well insulated. The exterior of the chamber was covered with laminated board. The interior of the chamber consisted of a heater compartment, a false floor, a baffle, and a space for receiving the commodity to be treated. Heat was applied by a nonglowing strip heater located in the small compartment partitioned off the end, and a 10-inch ventilating fan circulated the air out through the load and back through the air duct formed by the false floor.

The chamber, the top of which was a removable cover that fitted against double gaskets, was approximately the size and shape of a shipping crate for nursery stock (outside dimensions, 9 feet long, 2 feet, 5 inches wide, and 3 feet high). During fumigation it was loaded with either cherry seedlings prepared to simulate nursery stock or 50 to 300 dormant nursery trees. The fumigant was introduced into a shallow pan above the heater through a hole in the cover. Temperatures in the chamber were determined by thermometers inserted through the cover.

A constant exposure of 4 hours was used in both laboratory and commercial tests. Dosage and temperature were varied. Dosage is expressed in terms of pounds per 1000 cubic feet.

The concentration of the fumigant in this chamber during the treating period was tested by drawing samples of the air-gas mixture at intervals. A dosage rate of 2 pounds of methyl bromide per 1000 cubic feet, which is equivalent to 32 mg. per liter, showed concentrations of 31.7 mg. per liter at 10 minutes, 30.8 mg. at 2 hours, 29.5 mg. at 4 hours, and 22.5 mg. at 22 hours. There was only a decrease of approximately 7 per cent due to leakage or absorption during the 4-hour period.

The egg and the overwintering larval, pupal, and adult stages of the moth were employed. The method of rearing them has been described by Allen *et al.* (1940). Eggs used were from 2 to 13 days old and were laid on pear leaves. They were usually stored in a refrigerator before treatment and again, along with controls, for a period following treatment, after which they were incubated to induce hatching. The over wintering larvae were cocooned in strips of corrugated paper, in small bundles of tightly bound twigs (Fig. 2), and in holes bored in peach twigs (Fig. 2), the last two conditions simulating natural overwintering locations. The pupae fumigated were in cocoons in corrugated paper strips. The adults used in the experiments were usually newly emerged and were confined in screen cages during fumigation. The insects were placed at randomized locations in the chamber.[1]

FIG. 2.—Left: Bundled peach twigs infested with cocooned larvae of the Oriental fruit moth, used in toxicity experiments with methyl bromide. Right: Hole-bored peach branches infested with cocooned larvae of the Oriental fruit moth, used in toxicity experiments with methyl bromide.

In several instances nursery trees fumigated were planted out for observation of growth along with control lots. This phase of the work is still in progress and will be reported upon its completion.

RESULTS.—In the laboratory tests methyl bromide was found to be more toxic and promising than trichlorethylene, ethyl formate, a mixture of ethylene oxide (25 per cent) and ethylene dichloride (75 per cent), or ethylene dichloride alone. About 40 miscellaneous tests were made with various dosages of methyl bromide at different temperatures and at various exposures. These preliminary data are not included here, but the results indicated that survivals occurred with 1 pound of

[1] The insect material was furnished by the Moorestown, N. J., laboratory of the Bureau of Entomology and Plant Quarantine. The cooperation of H. W. Allen and assistants is acknowledged.

methyl bromide per 1000 cubic feet for a period of 3 hours at approximately 70° F. and with 4 pounds of methyl bromide for 3 or 4 hours at about 50°.

Data on the commercial tests are given in table 1. In the fumigations of eggs at 60° F., dosages ranging from 1 to 3.5 pounds were used, 2.5 pounds being the lowest that produced complete mortality. In fumigations at 70° and higher, dosages of 2 to 3.5 pounds were used, and all produced 100 per cent mortality. A total of 15,623 eggs were treated; the control lots totaled 13,899 and had an average mortality of 4 per cent.

Table 1.—Fumigation of eggs, larvae, and adults of the Oriental fruit moth with methyl bromide at atmospheric pressure for 4 hours.

Number of Tests	Dosage in Pounds per 1000 Cu. Ft.	Temperature in °F.	Fumigated Insects	
			Number	Per Cent Killed
		Eggs		
1	1	60	816	97
1	1.5	60	1,033	99
1	2	60	596	34
6	2.5	60	5,766	100
2	3	60	1,218	100
1	3.5	60	596	100
4	2	68–71	2,735	100
1	2	75–78	346	100
2	2.5	71–78	1,597	100
1	3	69–72	491	100
1	3.5	70–73	429	100
		Larvae		
1	1	60	302	95
1	1.5	60	312	100
7	2	60	1,517	100
8	3	60	2,256	100
3	3.5	60	413	100
4	4	60	596	100
1	1	70	164	100
2	1.5	70	589	100
5	2	70	1,108	100
15	2.5	70	3,894	100
12	3	70	4,217	100
9	3.5	70	1,995	100
20	4	70	4,264	100
		Adults[1]		
1	.5	58	100	100
1	.75	59	100	100
1	1.5	60	100	100
1	1.5	60	1,000	100
1	2	60	500	100
1	2.5	60	1,000	100
1	.25	74–77	500	100
1	.5	74–77	500	100

[1] The number of adults fumigated was estimated.

Fumigated larvae were divided into two lots. One lot was removed from the cocoons for observations on mortality following treatment. The other lot remained in the cocoons from 17 to 86 days before being removed and examined. The latter procedure more nearly approximated commercial conditions. Since no noticeable difference between the mortalities of the two lots was apparent, the data were combined. In experiments at 60° F. dosages ranging from 1 pound to 4 pounds were employed. The lowest dosage that killed all larvae was 1.5 pounds. At 70° the dosages ranged from 1 to 4 pounds, and the lowest killed all larvae. A total of 21,627 larvae were treated. In control lots mortality ranged from 40 to 50 per cent.

Pupae were fumigated in 12 tests. Dosages of 2.5 and 3 pounds at 60° and of 1.5 and 2 pounds at 70° gave complete mortality. A total of 1200 pupae were treated. The mortality among 210 pupae in the control lots averaged 28.7 per cent.

At approximately 60° F. dosages of 0.5 pound to 2.5 pounds and at approximately 75° dosages of 0.25 to 0.5 pound gave complete mortality of adults. Approximately 3800 adults were fumigated.

A series of vacuum-fumigation tests also was performed in which the pressure was reduced to the equivalent of 2 inches of mercury at sea level (28-inch vacuum). Complete mortality was obtained with 1 pound of methyl bromide for 2 hours at 70° F., with 2 pounds for 4 hours at 55°, and with 4 pounds for 2 hours at approximately 50°. However, a dosage of 1 pound at either 2- or 4-hour exposures at approximately 45° did not kill all the larvae.

COMMERCIAL APPLICATION.—In 1938, treatment with 3.5 pounds of methyl bromide per 1000 cubic feet for 4 hours at 70° F. was recommended by the Bureau and accepted by the western states as a condition of entry of the hosts of the Oriental fruit moth. Some tip injury occurred in experimental tolerance tests and in commercial practice from this dosage, and further experimental work with various stages of the insect during the winter of 1938–39 showed that the dosage and temperature could be appreciably lowered without impairing the efficacy of the treatment. Therefore new treatment schedules consisting of 2 pounds of the fumigant per 1000 cubic feet at 70° or 3 pounds at 60° for 4 hours were recommended by the Bureau and accepted by the western states. These treatments provided an ample safety factor to compensate for

any irregularities in commercial application and lessened the probability of plant injury.

SUMMARY —Because of the quarantines placed against nursery-stock hosts of the Oriental fruit moth, *Grapholitha molesta* (Busck), by the western states, experimental work was undertaken to develop a quick and economical method of treatment. Trichlorethylene, ethyl formate, methyl bromide, a mixture of ethylene oxide and ethylene dichloride, and ethylene dichloride alone were tested, and methyl bromide was selected as the most promising.

All stages of the insect were tested, the eggs and larvae being the most resistant. Dosages of 1.5 pounds of methyl bromide per 1000 cubic feet for a period of 4 hours at 60° F. or 1 pound at 70° were found to be lethal to overwintering larvae (the stage occurring on dormant nursery stock) in atmospheric fumigations. Recommended dosages for commercial use were 3 pounds per 1000 cubic feet for 4 hours at 60° or 2 pounds for 4 hours at 70°.

Dormant nursery stock was tested for tolerance. The results of these and subsequent tests at the recommended dosages will be reported later —6-12-42.

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Diapause and Egg Intoxication in *Diprion polytomum* Hartig[1]

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In consulting the literature for previous studies on the diapause of sawflies (Gobeil 1941), one of the numerous papers of Roubaud on this subject attracted more especially my attention. Roubaud's theory is pretty well known now. According to him the diapause would be a spontaneous inactivity, independent of low temperatures, resulting from an hereditary intoxication caused by the accumulation of excretory products in the organism. These products can be urates, ammonium carbonates, calcium carbonates or guanine. A state of temporary inactivity at low temperature (athermobiosis) or a low humidity (anhydrobiosis) is necessary to allow the excretory organs to purify the organism, which can then resume its development. From those true or spontaneous diapauses (asthenobiosis), where the pause in the evolution takes place without any apparent external cause, Roubaud distinguishes the common or pseudo-diapauses due to unfavorable environmental conditions. Finally the true diapauses, besides being obligatory and hereditary, would in some cases appear regularly, while in other cases they are cyclical. It can be seen that this theory, criticized by many, is elastic enough to be adapted to all types of hibernating insects.

More recently, in the paper already referred to, Roubaud (1935) explains the diapause of *Phlebotomus pappatasii* by the influence exerted by the female organism. Using females obtained from active parents, he divides them into two lots. Those which are permitted to oviposit without delay give birth to a progeny without diapause. In the second lot, the oviposition is delayed from 8 to 9 days and the offspring are all torpid individuals, the development of which is deferred in the fourth stage. Similar experiments, with other types of hibernating insects, gave identical results. From those facts, Rou-

[1] Contribution No. 17. Ent. Serv. Dept. Lands & Forests, Que. Canada.

baud concludes that this state of asthenobiosis or diapause would be conferred in certain cases to the offspring when the eggs are kept in the female body for an abnormal period of time and become overloaded with elements inhibiting development.

Roubaud's experiments with *Phlebotomus* were very conclusive and there were reasons to believe that his hypothesis could offer some possibilities for *Diprion polytomum*. With this insect, long diapauses are observed chiefly in one generation areas, *i.e.* in the northern part of its range. In those regions it is common to have at the beginning of the summer a warm spell, resulting in a high percentage of emergence, followed by many cold days preventing oviposition, whence egg intoxication. It would not be the same more southward, especially for the second generation, in the middle of the summer, when then, only a long period of rain may prevent oviposition. It would be why, in the southern part of its range, long diapauses would be less frequent. Therefore, a few days of cold or rainy weather, rendering the females inactive when emergence is at its peak, would give rise to offspring presenting long diapauses. As a result the percentage of emergence the following year would be much lower. Roubaud's hypothesis, if it hold good for *Diprion polytomum*, would permit in one generation areas, to forecast one year ahead the abundance of the spruce sawfly by following very closely the climatic conditions during the relatively short period of adult emergence.

The degree of intoxication, if there is intoxication, should vary with the age, the activity and the food of the female. Accordingly the individuals used in my experiments were divided into four groups:

A.—The females are confined in a dark and cool environment, 50 to 55° F., so that they waste the minimum energy.

B.—Individuals are left in daylight in the insectary, average temperature 60° F at night and 70° F. in daytime, with sugared water as food.

C.—Same condition as B, but without food. In this environment we should expect the maximum intoxication, *i.e.* longer diapauses, for period of confinement corresponding to environments A and B.

D.—Here no pressure is made on the females. Right after emergence they are placed on fresh foliage for oviposition. However, every two days, they are transferred to new foliage to know approximately the age of the parents of the offspring.

According to the number of days in confinement, the individuals of groups A, B and C were subdivided into lots of 25 females, each having respectively 1 and 6 days of reclusion, during which the females were placed individually in short-necked bottles, 5 inches high and 3 inches in diameter, covered with muslin.

The females used for these experiments emerged between June 1 and 15 from cocoons kept in incubator at 75° F. and 85% rel. hum. Oviposition took place at 70° F. between June 8 and 15, and the larvae were reared at 75° F. and 60% rel. hum. Larval development varied from 31 to 34 days. The newly formed cocoons were left in incubator for a month and then opened and analyzed. A summary of the results obtained is presented in table 1.

Table 1.—Influence of confinement before oviposition on the length of the diapause of *Diprion polytomum*.

	Environment							
	A		B		C		D	
Period of confinement in days	1	6	1	6	1	6	1	8
Number of cocoons formed	5	—	9	2	7	1	2	12
Emergence after 30 days in incubator	—	—	—	—	1	—	1	1

Apparently, the speed of development within the cocoon, *i.e.* the length of the diapause, is not at all influenced by the number of days the female will remain in confinement before oviposition.

It must be emphasized however, that if we consider separately each environment we do not have enough individuals to arrive at any conclusion. Indeed, in environment A, no cocoon was obtained after 6 days of reclusion, while for the same period only one was obtained in environment C. On the other hand, if independently of the environment, we divide into two groups the cocoons obtained from eggs laid 1 and 6 days after the emergence of the females, we have 23 individuals for the first group and 15 for the second group with 2 and 1 emergence respectively. Therefore, even if we consider the results under this new angle, the

length of the diapause seems absolutely independent of the retention period of the mature eggs in the ovaries and, apparently, Roubaud's hypothesis on the intoxication of the eggs would not apply to *Diprion polytomum*.

It is more probable that the answer to those long diapauses of the european spruce sawfly in the northern part of its range lies rather in the influence of unfavorable environmental condition, not only before incubation, but during the whole life cycle. Yet, before rejecting Roubaud's hypothesis, it might be advisable, considering the small numbers of individuals used in the present experiments, to repeat them with at least a hundred cocoons for each environment and each different period of confinement. —3-14-42.

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Cooperative Distribution of Organisms Causing Milky Disease of Japanese Beetle Grubs[1]

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The existence of bacterial diseases among Japanese beetle grubs, *Popillia japonica* Newm., has been known for some time. Since 1934 the so-called milky disease, caused by two species of bacteria, first referred to as types A and B (White & Dutky 1940) and later described as *Bacillus popilliae* and *B. lentimorbus* (Dutky 1940), has become increasingly important. The present paper relates chiefly to the first-mentioned species, which is the more common of the two.

Although milky disease appeared to be a major factor in the natural control of the beetle in certain localities, it was found to be present for the most part only in the older infested areas, and its natural spread has lagged behind that of the beetle. Because of the widespread interest in the use of the disease organisms for Japanese beetle control, and in order to accelerate their natural spread, an extensive program of distribution has been undertaken by the Bureau of Entomology and Plant Quarantine, of the United States Department of Agriculture, and a number of cooperating state and federal agencies.

PREPARATION OF MATERIAL FOR DISTRIBUTION.—Milky disease bacteria lend themselves readily to handling for field distribution because of the long life of the spores and their extreme resistance to a wide range of temperature and moisture conditions (White 1940). Since culture media in which the organisms will develop to the spore stage are not available, they are propagated in the bodies of the grubs themselves, by a method developed at the Moorestown, N. J., laboratory.[2]

Although the organisms may be applied in water suspension, the most practical way of handling them is in the form of a dust, with talc as the carrier. Each gram of the mixture is standardized to contain 100 million spores, and thus any desired dosage can be readily applied.

METHODS OF APPLYING THE SPORE-TALC DUST.—Experimental data have indicated that if 2 grams of standardized spore dust is applied per spot (approximately 1 square foot) at intervals of 10 feet, where a moderate-to-heavy larval population occurs, the organism within three larval feeding seasons will be distributed throughout the untreated portions by local migration of the larvae. With spring treatments the dissemination of the organism throughout the area will occur by the end of the second season. Although a quicker build-up of the disease can be expected when a treated area is

[1] Eastern Branch Program, Baltimore, 1941.
[2] A detailed description of this method, as well as a method for the preparation of the spore-talc dust, in manuscript.

completely covered, the amount of material needed for such a treatment is very much greater. The 10-foot-interval treatment has therefore been chosen for colonization work in most areas. In certain areas existing conditions may warrant a change in the rate of application. To meet the requirement the interval between spots is changed, but the amount of material applied per spot remains constant.

A hand corn planter of the rotary type has been used in applying the spore-dust material. The planter can be adjusted to deliver accurately 2 grams of material per operation and holds $1\frac{3}{4}$ pounds, a quantity sufficient to treat 1 acre when applied at intervals of 10 feet. Manipulation of the planter is exceedingly simple. It is used as a walking stick, and with a little practice the operator can release the material at uniform distances. The planters have been so modified that the material is not dropped all at once and deposited in a heap, but rather is released gradually so that it is spread over a longer distance as the operator walks along.

DISTRIBUTION PROGRAM.—The details of the arrangements for the cooperative program have been varied to meet the special needs of the agencies involved. The manner of treatment and the size of the areas treated have also been varied to fit conditions arising in programs conducted by the different states. The following paragraphs discuss briefly the cooperative arrangements with each state in which colonization programs have been undertaken and show the progress made to date (November 1, 1941).

New Jersey.—The Bureau undertook a colonization program during the fall of 1939 in cooperation with the New Jersey Department of Agriculture. In this program both the milky disease and a parasitic nematode, *Neoaplectana glaseri*, were distributed. The colonization points were placed at intervals of approximately $3\frac{1}{2}$ miles. A total of 450 sites, comprising 332 acres, have been treated with milky disease in the colonization of the entire state, with the exception of Sussex County.

Maryland.—Cooperative work was also started by the Bureau and the Maryland Agricultural Experiment Station in the fall of 1939, but on a different plan from that used in New Jersey. In the arrangement with this state the Bureau furnishes the micro-injectors, stock culture slides for preparing the inocula, and any available technical information needed. The State then digs the larvae and inoculates and holds them for disease development. The diseased larvae are then delivered in ice water to the Bureau laboratory at Moorestown, where they are "processed," that is, ground and mixed with talc. The standardized spore-dust material thus prepared from these larvae is then returned for field distribution by the state workers. Under this arrangement the Bureau has supplied 4 micro-injectors and 3528 culture slides, has processed 522,477 diseased grubs, and has returned to the Maryland authorities 22,440 pounds of spore dust. With this material the State thus far has treated some 21,750 city and farm properties.

New York.—A program has been carried on by the Bureau in cooperation with the New York Agricultural Experiment Station since 1940. Culture slides and a micro-injector were furnished the State by the Bureau for preliminary work on the same basis as that used with Maryland. From 12,803 diseased larvae brought to the Moorestown laboratory for processing, 482 pounds of spore-dust material were prepared. In addition, 496 pounds of standardized spore-dust material was furnished by the Bureau for use in the heavily infested beetle area of that state. Under the cooperative arrangement the state agency collected 100,000 Japanese beetle larvae, which were sent to the Bureau laboratory at Moorestown for inoculation and use in the preparation of spore-dust material. To date some 124 colony sites, totalling about 158 acres, have been treated. A colony site is considered to be any individual location, such as a golf course, on which any number of half-acre plots have been treated, a half-acre being the unit of treatment. In the heavily infested areas and on golf courses and similar large turf areas the plan has been to treat 1 half-acre in each 10 acres of turf, while in the open country two half-acre plots per square mile have received treatment.

Virginia.—The Bureau has cooperated with the Virginia Department of Agriculture and Immigration in colonizing heavily infested areas in that state. A total of 128 colonies including 83 acres have been treated. These areas are exclusive of government-owned premises

adjacent to the District of Columbia and consist principally of permanent pasture lands in Accomac, Northampton, and Loudoun Counties. The Bureau has furnished approximately 157 pounds of spore-dust material, while the field application has been made by the State.

Connecticut.—The Bureau has cooperated with the Connecticut Agricultural Experiment Station in the colonization of infested areas with milky disease, and in 1941, furnished approximately 1235 pounds of spore-dust material for application throughout the heavily infested beetle area. Culture slides, as well as a micro-injector, were also furnished for the purpose of acquainting Experiment Station workers with the technique of inoculation. Ten thousand inoculated larvae forwarded to the Moorestown laboratory in 1940 were processed, and 203 pounds of the final standardized product were prepared and returned for distribution by the State in experimental field work. A total of 258 locations, involving about 478 acres, have been colonized by the State representatives, exclusive of a number of experimental plots and government areas treated by the Bureau, which also serve as colonization points. The Connecticut workers also collected 100,000 Japanese beetle larvae and forwarded them to the Moorestown laboratory for inoculation and use in the production of spore-dust material.

Delaware.—The cooperative arrangement between the Bureau and the Delaware Agricultural Experiment Station has resulted in the treatment of 1144 acres throughout the state. These treatments were placed as far as possible in permanent pastures, two half-acre plots per square mile. Several of the larger towns and cities received some additional treatment. For this work the Bureau has furnished 2520 pounds of spore-dust material, the field application being handled by the State.

Pennsylvania.—A cooperative program has recently been undertaken by the Pennsylvania Department of Agriculture and the Bureau. A total of 558 locations involving 490 acres have been treated in the heavily infested area. The Bureau has furnished 1637 pounds of spore-dust material, the field application being handled by the State.

Ohio, Rhode Island, and West Virginia.—A few colonies of milky disease have been released in each of these states in cooperation with the State agencies.

North Carolina.—Approximately 300 acres at Asheville were treated with milky disease by the Bureau to determine experimentally the effect of the introduction of the disease in an isolated beetle infestation. The entire area was treated at intervals of 10 feet, and a portion was retreated, the rate of application in that portion therefore being increased above the normal colonization rate.

Government Reservations.—In addition to the cooperative state programs a number of government reservations throughout the heavily infested beetle area have been treated by the Bureau in cooperation with the various Federal agencies concerned. These include army and navy reservations, veterans hospitals, and national parks and cemeteries. Owing to the large continuous areas of turf involved, and the generally heavy larval populations present, the treatment at these areas has been somewhat more extensive than that in strictly colonization work. The entire turf area at each reservation was spot-treated at 10-foot intervals on lines 20 feet apart, a procedure which should insure a rapid spread and build-up of the disease organism. Over 5500 acres of government areas have been treated.

A summary of milky disease colonization up to November 1, 1941, is given in table 1, which shows a total of 20,834 acres treated by the Bureau in cooperation with the state and federal agencies concerned. Not included are 260 experimental plots, totalling 92 acres, distributed in 7 states and the District of Columbia, which also serve as points of local dispersion of the disease.

SUMMARY.—Early observations in the areas longest infested by the Japanese beetle indicated that diseases were important in the reduction of this insect. Methods for producing economically sufficient quantities of milky disease spores and for distributing them in field treatments have been developed by the Bureau of Entomology and Plant Quarantine, of the United States Department of Agriculture. In an effort to accelerate the natural spread of these diseases the Bureau has undertaken an extensive colonization program using the organisms causing milky disease, in cooperation with

Table 1.—Colonization of milky disease of Japanese beetle.

State	Colonization			Treatment of Government Reservations		Total Number of Acres Treated
	Number of Counties	Number of Colonies	Number of Acres Treated	Number Treated	Number of Acres Treated	
1939						
New Jersey	6	161	125	—	—	125
1940						
District of Columbia	—	—	—	26	1,342	1,342
Maryland	23	8,843	4,533	—	—	4,533
New Jersey	14	256	195	—	—	195
New York	1	8	33	—	—	33
Virginia	3	7	7	8	72	79
Total	41	9,114	4,768	34	1,414	6,182
1941						
Connecticut	6	258	478	2	88	566
District of Columbia	—	—	—	5	168	168
Delaware	3	2,307	1,144	1	90	1,234
Maryland	23	12,907	7,783	8	1,165	8,948
New Jersey	4	33	12	11	547	559
New York	8	116	125	14	1,445	1,570
North Carolina	1	1	300	—	—	300
Ohio	3	3	2	—	—	2
Pennsylvania	12	558	490	3	304	794
Rhode Island	1	6	5	—	—	5
Virginia	5	121	76	2	300	376
WestVirginia	4	8	5	—	—	5
Total	70	16,318	10,420	46	4,107	14,527
Grand Total[1]	86[2]	25,593	15,313	80	5,521	20,834

[1] Not included are 260 experimental plots, totalling 92 acres, distributed in 7 states and the District of Columbia, which also serve as points of local dispersion of the disease.
[2] Actual number of counties treated.

the appropriate agencies in 11 States and the District of Columbia. The details of the cooperation between the agencies has been varied to meet the specific needs of the agencies involved. Certain special equipment necessary for the program and available technical information needed were furnished the various cooperative agencies by the Bureau. As a result of this cooperative program almost 21,000 acres, comprising 25,593 colony sites, have already been treated with milky disease in the heavily infested beetle areas. In addition, 260 experimental plots distributed in 7 States and the District of Columbia also serve as colonization sites.—11-24-42.

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BUY MORE WAR BONDS EACH MONTH

Influence of Leaf Age and Feeding Injury on the Citrus Red Mite

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Heavy infestations of the citrus red mite, *Paratetranychus citri* McG., often disappear rapidly, and the reduction cannot always be satisfactorily explained by climatic conditions or the presence of natural enemies. The feeding activity of the citrus red mite causes considerable injury to the foliage of citrus trees. This condition can be produced by a dense population feeding for a comparatively short interval, or by a less dense population the activities of which are extended over a considerable period. An excessive amount of injury was suspected of causing a decrease in populations by rendering the leaves unsuitable as food, but it was not until disproportionate reductions were obtained in trees having different population densities that this factor was clearly demonstrated.[2]

PROCEDURE.—To evaluate the effect of citrus red mite density and the resulting feeding injury on productivity and longevity, three laboratory experiments were conducted. Citrus leaves were placed in individual cages, and different degrees of injury were produced by varying the number of mites used to cause the injury. All dead mites in these cages were replaced daily so that the numbers used in producing injury would be fairly constant for the conditioning period. After several days of conditioning in this manner the mites and resulting eggs were removed by brushing, and a definite number of newly collected adult females were introduced into the cages. Egg-production and mortality records were taken at intervals for the duration of the tests.

INFLUENCE OF DENSITY AND FEEDING INJURY.—In the first two tests three levels of feeding injury corresponding to field-injury ratings of light, medium, and heavy were produced on orange leaves in the laboratory. Mortality and oviposition counts were taken at intervals of 24 and 48 hours in the first tests and 40 and 88 hours in the second test. The results of these counts are shown in table 1.

Table 1.—Living mites and eggs produced per cage during different feeding intervals on orange leaves having light, medium, and heavy feeding injury.

Feeding Interval, Hours	Average Number of Mites and Eggs for Indicated Injury Class					
	Light		Medium		Heavy	
	Mites	Eggs	Mites	Eggs	Mites	Eggs
			Test 1			
24	8.7	17.9	8.7	12.9	8.3	9.3
48	7.5	20.2	7.6	9.4	6.9	6.6
			Test 2			
40	8.9	11.3	8.9	4.3	9.0	3.6
88	7.2	9.5	6.8	4.2	6.6	2.7

There was a highly significant difference between the numbers of eggs produced on the lightly injured leaves as compared with the moderately and severely injured ones. To determine whether the decrease in egg production associated with the degree of feeding injury was caused by a relatively higher mortality of producing females or by a decrease in the rate of egg production due to unsuitable food conditions, the mean numbers of living female mites per cage were compared for the two feeding intervals in each test. No significant difference occurred in the average number of living mites between any of the injury types for any one interval. A comparison of the average number of living mites on leaves of the different injury types with the number of eggs produced indicated that egg production was not correlated with mite density, but was the result of leaf condition. As shown in table 2, the number of eggs produced per mite for the two feeding intervals in each test decreased as the amount of feeding injury increased.

The third test was conducted to determine the degree of sensitivity of the mite to smaller differences in feeding injury. Thirty orange leaves were placed in individual leaf cages and then divided into lots of five cages each, the number of mites used to cause feeding injury ranging from 5 to 30 per cage. The conditioning period was 5 days.

During the feeding period records were

[1] Calvin L. Stucker assisted the writers in making many of the population counts and otherwise aided them in the investigation.

[2] Unpublished manuscript by J. K. Holloway *et al.*

Table 2.—Egg production per mite in successive feeding intervals on orange leaves having light, medium, and heavy feeding injury.

Feeding Interval, Hours	Number of Eggs per Mite for Indicated Injury Class		
	Light	Medium	Heavy
	Test 1		
0 to 24	2.06	1.49	1.13
24 to 48	3.59	.93	.68
	Test 2		
0 to 40	1.26	.48	.40
40 to 88	1.40	.87	.43

Table 3.—Egg production per mite at various levels of feeding injury on orange leaves.

Initial Number of Mites per Cage	Number of Eggs per Mite After Indicated Feeding Interval			
	48 Hours	72 Hours	96 Hours	120 Hours
5	6.72	3.00	3.48	3.48
10	6.94	3.02	5.40	.84
15	7.01	3.15	3.36	2.97
20	6.79	3.55	3.22	2.34
25	5.04	2.53	2.22	1.13
30	6.26	2.89	1.97	1.21

kept of the number of eggs produced in the six lots. The first record was made 48 hours after the mites had been placed on the leaves, and the remaining three counts were made after each succeeding 24-hour period. In table 3 the ratios of eggs to mites are shown.

During the first and second periods, before any appreciable injury to the leaves had resulted, there was no appreciable difference in egg production between the different injury levels. This indicates that within the density ranges used there was no immediate influence on oviposition attributable to the number of mites per cage. The influence of feeding injury as a factor inhibiting egg production did not become apparent until the third and fourth periods.

The influence of previous injury on egg production and longevity was tested by placing 10 adult female mites in each of the cages containing leaves injured by the feeding of various numbers of mites. The egg production for four successive 24-hour periods is shown in table 4.

Under the conditions of the experiment it was not possible to show a significant difference in egg production for each increase of injury caused by a difference of five mites per cage. There was a highly significant difference in production between the injury caused by 5 mites as compared with the remaining injury classifications. When the injury classifications were grouped in combinations of 5 to 10, 15 to 20, and 25 to 30 mites, there was a highly significant difference in egg production between the various injury types. The initial difference occurring in the first 24-hour period remained proportional for the various injury types during the succeeding periods, and the total number of eggs produced showed a highly significant decrease after the first 24 hours.

The mortality of mites feeding on leaves having various degrees of injury was also recorded for the 24-hour periods. The influence of feeding injury on the mortality of mites is shown in table 5.

There was a slight increase in mortality associated with feeding injury. Mortality increased with time, the greatest increase being for the last 24-hour period. The greatest proportionate reduction of mites for this period was associated with the

Table 4.—Egg deposition in successive feeding periods. Total for each injury class per period based on 5 cages of 10 mites each.

Feeding Period, Hours	Number of Eggs Deposited for Indicated Injury Class						
	5 Mites	10 Mites	15 Mites	20 Mites	25 Mites	30 Mites	Total
24	172	162	138	140	111	137	860
48	107	66	53	46	26	36	334
72	106	72	55	32	22	26	313
96	82	48	38	30	8	15	221
Total	467	348	284	248	167	214	—
Group Total	815		532		381		

Table 5.—Mite survival in successive feeding periods. Total for each injury class per period based on five cages of 10 mites each.

Feeding Period, Hours	Number of Test Mites Surviving for Indicated Injury Class						
	5 Mites	10 Mites	15 Mites	20 Mites	25 Mites	30 Mites	Mean
24	45	47	45	41	44	46	44.67
48	42	47	43	39	38	39	41.33
72	41	43	41	34	33	37	38.17
96	31	35	37	28	25	33	31.50
Mean	39.75	43.00	41.50	35.50	35.00	38.75	—
Group Mean	41.38		38.50		36.88		—

leaves having the least injury. The greatest reduction on leaves having the most injury occurred during the first and second periods.

Two reactions of the citrus red mite to leaf injury have been observed, namely, a high reduction in egg production accompanied by a slight increase in mortality. This would indicate some form of nutritional influence, which had a more pronounced effect on egg production than on mortality. A comparison was made of the egg production per mite for the various degrees of injury. A summary of the comparisons is presented in table 6.

Table 6.—Egg production per mite on leaves of various injury classes during a period of 96 hours.

Initial Number of Mites per Cage	Number of Eggs Produced per Mite	
	Mean	Group Mean
5	2.77	2.35
10	1.94	
15	1.65	1.63
20	1.62	
25	1.09	1.20
30	1.31	

The ratio of eggs to mites was used to correct for the slight differences in mortality. This ratio would be about equal for the various degrees of injury if egg production was highly correlated with mortality. The ratios were found to decrease as the amount of feeding injury increased.

It should be noted that conditions other than feeding injury can cause a decrease in oviposition. In the injury class caused by the feeding of 25 mites per leaf there was a greater decrease in egg production than expected. This condition also prevailed in the conditioning period before feeding injury was a factor (Table 3).

Possibility of a Toxic Reaction.—Since the feeding of the citrus red mite could cause the formation of toxic products which might be detrimental to productivity, an experiment was designed to test the influence of feeding independent of surface conditions. Lemon leaves were placed in individual leaf cages, and half of each leaf surface was masked to prevent contact by the mites. In one lot 15 mites were confined in each cage while the other lot was uninfested. At the end of 5 days the mites were removed from the test cages, the mask was placed over the fed-on portion of the leaf, and 5 newly collected mites were introduced into each cage. In this way all test mites were feeding on uninjured surfaces, but in one series the opposite half of the leaf had been severely injured. There was no significant difference in the numbers of living mites or eggs produced over a 48-hour period, an indication that the feeding of the mites had no toxic effect transmissible from one portion of the leaf to another that would cause a decrease in the egg production or in the longevity of the adult.

Effect of Leaf Age.—Definite growth cycles usually occur on orange trees during the fall and spring, and field observations indicate that red mite populations are more abundant during these periods than at any other time of the year. Furthermore, when the flush-growth appears, the mite populations are usually more abundant on the new growth. Later the populations are more evenly distributed in the foliage of the tree, and as the summer

progresses populations decrease. During this season the leaves are also maturing, and it was thought that leaf age might have an important influence on the reduction of populations.

To determine the effect of leaf age on the mortality and reproduction of the citrus red mite, young, medium, and old leaves were tested. The numbers of eggs produced on young and medium-age leaves were significantly greater than on older leaves. No significant difference occurred between the young and medium-age leaves in respect to the mortality of the female mites or the number of eggs produced, although more eggs were produced on the young leaves. From the results of this experiment it can be inferred that with insufficient new growth maximum egg production will not occur.

FEEDING INJURY AND LEAF AGE.—Both feeding injury and leaf age have been demonstrated as important factors in decreasing citrus red mite populations by limiting egg production and longevity. An experiment was conducted to compare these two influences. Citrus red mite densities of 10 and 20 mites per leaf were used to cause injury on young and medium-age leaves. At the end of each 24-hour period the dead mites were replaced, so that during the 6-day conditioning period the leaves had a fairly constant number of mites causing injury.

During the first two 24-hour conditioning periods egg production records were taken to observe the influence of mite density on the two age classes before the feeding factor became dominant. Within either foliage-age class there was no difference in egg production between the two 24-hour periods at a given mite density. The production of eggs was significantly lower on the medium-age leaves. This difference was independent of the number of live mites per cage, being due to the condition of the leaf.

At the end of a 6-day conditioning period the mites and eggs were removed from the leaves and 10 newly collected adult female mites were placed in each cage. This part of the experiment included a check consisting of leaves of the two age groups which were collected and prepared with the other leaves, but which did not have any feeding injury. The results of the egg-production records are presented in table 7.

Table 7.—Living mites and eggs produced per cage for two leaf ages and three levels of feeding injury.

Number of Mites Causing Injury	Flush-Growth Leaves		Medium-Age Leaves	
	Number of Eggs	Number of Living Mites	Number of Eggs	Number of Living Mites
None	35.2	7.4	9.9	7.2
10	26.0	9.0	8.7	8.0
20	15.9	8.4	10.4	6.1

Feeding injury influenced egg production to a much greater extent on flush-growth leaves than on the medium-age leaves. There was a significant reduction in egg production between flush-growth leaves having no injury and ones having injury resulting from the feeding of 10 and 20 mites per cage, while on medium-age leaves there was no difference in egg production between the injury types. The total production on medium-age leaves was lower than on flush-growth leaves.

SUMMARY.—Populations of the citrus red mite often decrease rapidly when climatic conditions are apparently favorable and natural enemies are extremely scarce. Leaf injury caused by the feeding of the mites is shown to be a factor capable of causing this reduction.

Within the density ranges tested there was no direct influence on the oviposition attributable to the number of mites per cage, the reduction being due to the resulting feeding injury. There was a slight increase in mortality associated with feeding injury.

The reduction in egg production associated with leaf injury was not due to any toxic condition transmissible from one portion of the leaf to another.

The numbers of eggs produced on young and medium-age leaves were significantly greater than on old leaves. Feeding injury influenced egg production to a much greater extent on flush-growth leaves than on older leaves.—1-6-42.

Propagation of Black Scale on Potato Sprouts[1,2]

STANLEY E. FLANDERS,[3] *University of California Citrus Experiment Station, Riverside*

The propagation of the black scale, *Saissetia oleae* (Bern.), on potato sprouts aided materially in the establishment of the parasite *Metaphycus lounsburyi* (How.) in California (Smith & Compere 1920). It was found, however, that "the production of the black scale on potato sprouts or other host material is not a simple matter, and experience and knowledge of how to handle both the potato sprouts and the scale are of greatest importance" (Smith 1921).

In 1933, under the direction of Harry S. Smith, preparation was begun at the University of California Citrus Experiment Station for the mass production of black scale to be used in the propagation of parasites from South America and Africa. Subsequently, two hymenopterous parasites, *Lecanobius utilis* Compere and *Coccophagus heteropneusticus* Compere, reared from material obtained by Compere in South America (1934–35), were successfully propagated and distributed. *L. utilis* became established in California. Ten other species of parasites, reared from material obtained by Compere in Africa (1936–37), were also successfully propagated and distributed. Of this group, five species (*Coccophagus rusti* Compere, *C. cowperi* Gir., *C. pulvinariae* Compere, *Metaphycus stanleyi* Compere, and *M. helvolus* [Compere]), have become established.

All of these species were propagated and distributed in California by local insectaries. Production methods were those proposed by the Citrus Experiment Station, each insectary modifying the procedure to suit its particular requirements. Originally, most of the insectaries were built for the purpose of growing potato sprouts for the production of mealybugs. Black scale cannot be grown successfully, however, on the type of sprout required for mealybug production; the type used by Smith & Compere proved to be the most satisfactory.

GROWING POTATO SPROUTS FOR BLACK-SCALE PRODUCTION.—Potato sprouts for mealybug production are grown in very much subdued light, because the settling of the mealybug crawlers tends to be inhibited when the sprouts are green. (Smith & Armitage 1931). In black-scale production, on the contrary, green sprouts are most favorable for the settling down of the young crawlers; a certain amount of light is consequently needed in growing the sprouts. For maximum efficiency in production of the scale, the potato sprout should be nearly leafless. Light promotes leaf growth; it must therefore be so regulated that the amount of chlorophyll produced is sufficient and the stalk-leaf ratio is adequate for scale production.

FIG. 1.—Phototropic collection of young black scale (crawlers). A stack of twigs heavily infested with mature black scale is placed in front of a window. Note the mass of crawlers which have moved from the twigs toward the light and have collected at the angle formed by the two pieces of cardboard.

At first it was thought that sprouts could be grown in darkness until they were 6 or 8 inches in length and then brought into the light. Such sprouts took on a reddish hue, however, and comparatively few scales settled down on them. It was found advisable to keep the light condition constant from the time of planting. Light should be uniformly distributed in the rooms so that the potato

[1] Paper No. 468, University of California Citrus Experiment Station, Riverside, California.

[2] Credit for working out various refinements in the technique of large-scale production of black scale on potato sprouts must be given to Glenn L. Finney, who has been in charge of insectary operations at the University of California Citrus Experiment Station, Riverside, since 1937.

[3] Associate Entomologist in the Experiment Station

stalks grow in a vertical position. Scales on such sprouts are least subject to suffocation from excess deposits of honeydew.

The black scale thrives best on stocky, tough-fibered sprouts grown under fairly arid conditions. If the atmospheric humidity or the soil moisture is high, sprouts are long and succulent and do not hold up satisfactorily.

Under insectary conditions, the best sprouts are obtained when grown at proper light intensities, at a temperature of about 70° F., and at a relative humidity of about 60 per cent, with soil moisture maintained almost at the wilting point. The tubers are watered at the time of planting and thereafter only when necessary to keep the plant tissues turgid. Since the tubers supply the food material, watering is merely a method for regulating growth. The soil receives a small amount of water when the sprouts are washed to remove the honeydew, as described below. Excessive waterings lower the vitality of the sprouts.

Potatoes for black-scale production are planted as for mealybug production (Smith & Armitage 1931), but only about half as many tubers are planted per tray. Very old potatoes are unsuitable, since they tend to produce tubers instead of sprouts. If the potatoes have been held in cold storage, several days should elapse between removal from storage and planting. Bliss Triumph potatoes, which are grown at high altitudes, have proved satisfactory.

The planted trays are placed in racks on shelves about 20 inches apart. When the sprouts are about 6 to 8 inches in length, they are infested with young black scale.

PROPAGATION OF SCALE FOR PARASITIZATION.—The black-scale material for infesting the sprouts is, as a rule, obtained in the field from plants on which the scale is attended by ants. Because of such attention the scale is usually in a healthy condition and more or less free from predaceous mites and parasites.

The collection of the young scales (crawlers) is facilitated by the positive phototropic habit of the newly hatched young (Fig. 1). When twigs infested with mature scales are placed on a smooth surface near a window, the young scales crawl toward the source of light until they reach a point where the light intensity diminishes. If that point is marked by sharply defined, converging shadows, the crawlers accumulate in a pile (Fig. 1). They are then transferred to a sheet of paper and carried to the sprouts to be infested.

Trays in which the sprouts are of proper length are turned up on end above a smooth sheet of paper. The crawlers are then "dusted" over the sprouts. Those not adhering to the sprouts collect on the paper below and are used to infest other trays.

At temperatures between 70° and 75° F., the crawlers settle down within 24 hours. The first molt occurs two and one-half weeks later. The second (final) molt occurs 5 weeks after hatching. When 2 months old, the scales are full grown and reproduction begins. The incubation period of the scale egg is about 2 weeks.

Each of the parasite species normally reproducing on the black scale is restricted in oviposition and development to host individuals of a certain range in size. This range varies with different parasite species, that of *Coccophagus ochraceous* How. being very narrow and that of *C. trifasciatus* Compere very broad.

The parasites of black scale established in California attack the scale in sequence: *Scutellista cyanea* Motsch. feeds on the scale eggs; *Coccophagus ochraceous*, on the late first instar; *Metaphycus helvolus*, on the second instar; and *M. lounsburyi*, on the third instar (including the adult stage).

The degree to which it is advisable to infest the sprouts with scale is determined by the requirements of the parasite which is to be propagated. The smaller the stage of scale suitable for parasitization, the more heavily the sprout can be infested and the more scales utilized in less time.

The growing scales produce large quantities of honeydew, which they eject over their surroundings. In order to keep the scales from being smothered with honeydew, it is necessary to wash the sprouts about once a week. This is done by setting the trays on end and washing the sprouts with a coarse spray at a low pressure. Excessive humidity increases the water content of the honeydew, which causes it to flow under and over the scales. An indication of excessive humidity is the development of mold on the honeydew.

After the scales have been "stung" with parasites, washing is not necessary.

Enough parasites are placed on the trays of sprouts to "sting" most of the scales within 2 or 3 days. The room temperatures are then increased to 75° or 80° F.

Collection of the adult parasites from the "stung" scales is facilitated by cutting the scale-infested sprouts and placing them in collection cages (Fig. 2). This is practicable because of the uniformity in parasitization. The sprouts are cut when most of the parasites are in the pupal stage. Before the sprouts are spread out on the floor of the collection cages, they are allowed to dry for several days.

In growing most parasites, it is advissable to place a succession or rotation of infested sprouts in each room in order to obtain the maximum oviposition. In the case of such parasites as *Coccophagus trifasciatus*, however, rotation of sprouts within the room is not necessary.

In the production of *Metaphycus helvolus*, because of the host-feeding habit of this parasite and the consequent destruction of scales suitable for its reproduction, it is essential to regulate closely the number of females used in "stinging." For this reason it is not advisable to practice rotation in rearing this parasite. In fact, parasites such as *M. helvolus*, having a long oviposition period and short developmental period, do not reproduce to the full capacity under insectary conditions; for before these parasites deposit their complement of eggs, the host has become unsuitable, either because of increase in size or because of parasitization.

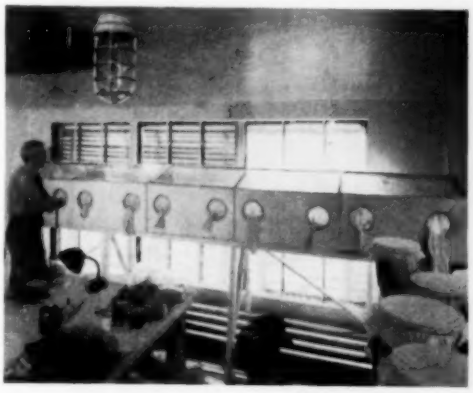

FIG. 2.—Cages containing harvested sprouts bearing parasitized scale from which parasites are emerging.

The use of green potato sprouts for the mass propagation of black scale is now as well established as is the use of bleached sprouts for the production of mealybugs. 4-22-42.

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NATIONAL PEST CONTROL ASSOCIATION CONVENTION

The annual convention of the National Pest Control Association was held in Pittsburgh, Pennsylvania on October 26, 27 and 28, with headquarters in the Wm. Penn Hotel where an excellent auditorium was available for the program.

The attendance was very good and the program most excellent. A more extended account of the convention will be provided in the December number of the *Journal*.

Metaphycus helvolus, an Encyrtid Parasite of the Black Scale[1]

STANLEY E. FLANDERS,[2] *University of California Citrus Experiment Station, Riverside*

The parasitic encyrtid *Metaphycus helvolus* (Compere) is one of twenty-eight species of parasites introduced into California from Africa by the University of California Citrus Experiment Station in 1937. It appears to be the most important of the twelve species of parasitic chalcidoids now established on the black scale, *Saissetia oleae* (Bern.), in California. A study of the physiological and ecological characteristics of *M. helvolus* has therefore been desirable.

Metaphycus Helvolus IN AFRICA.—Prior to its introduction and establishment in California, *Metaphycus helvolus* was not known to occur outside the Union of South Africa. According to Rust (Smith & Compere 1926), this parasite was very sporadic in its work on black scale at the Cape and appeared to be of little importance.

The apparently minor rôle of *Metaphycus helvolus* in the control of the black scale in South Africa may have been an effect of the introduction of the Argentine ant. According to Compere (1940), the introduction of this ant into Cape Town in 1902 was followed by an increase in the abundance of black scale on certain ornamental plants in that area. That is, the increase in the number of colonies of black scale seemed correlated with the increase and spread of the Argentine ant.

Unquestionably, concentrations of ants interfere more or less with the work of parasites. Gravid females of *Metaphycus helvolus*, for instance, require so much time to oviposit and to feed on host fluids (see "Host-Parasite Relations," p. 691) that where ants are present, these parasites are, to a great extent, replaced by less effective species that are quicker in oviposition and have no need for host fluids. Possibly, however, even the relatively small numbers of *M. helvolus* produced in the scale colonies fostered by ants tend to keep the scale population in surrounding areas at a lower density than would be the case otherwise.

Colonies usually wax, wane, and disappear (Flanders 1940). The ants, however, by cleaning up the scale excrement and by interfering with parasitization, tend to perpetuate the colonies of scale and to increase the density of individuals within the colonies. Since parasites increase in abundance with the host, the collection of black-scale parasites in South Africa in 1937 was facilitated by the presence of the Argentine ant. Parasitized scales shipped to Riverside were from ant-infested districts in which *Metaphycus helvolus* was able to maintain itself but in which other species of parasites were more numerous, as shown by the ratios of parasites obtained.

ECONOMIC IMPORTANCE OF *Metaphycus Helvolus* IN CALIFORNIA.—The ability of *Metaphycus helvolus* to control black scale in the field in California was first noted in 1939 in a citrus grove at Riverside and in an olive orchard at La Verne.[3] By the end of the year it was evident that *M. halvolus* had brought the infestations of black scale in these orchards under control.

These and other demonstrations of effective control stimulated the mass propagation of *Metaphycus helvolus* by the county and other cooperating insectaries. By the end of 1940, *M. helvolus* apparently occurred throughout the black-scale-infested areas of southern California. It is inherently able to disperse widely and rapidly, and dispersal was furthered by the extensive liberations of material reared in the various insectaries.

By the spring of 1941, *Metaphycus helvolus* had become the dominant parasite of the black scale in California, and infestations of the scale in areas where this parasite occurred had been reduced to the lowest status on record. The test of the efficiency of *M. helvolus*, however, will be its ability to maintain the black-scale populations at a point below that of economic injury. It is possible that *M.*

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[3] Glenn L. Finney, who has been in charge of insectary operations at the University of California Citrus Experiment Station, Riverside, since 1937, has been chiefly responsible for the successful mass production of this and other parasites of the black scale at Riverside.

helvolus may be as effective in the control of the black scale as *M. luteolus* (Timberlake) has been in the control of the soft (brown) scale, *Coccus hesperidum* L.

Metaphycus helvolus has been observed to reproduce on several other species of lecaniine scales, including *Saissetia nigra* (Nietn.), *Lecanium corni* Bouché, *Coccus pseudomagnoliarum* (Kuw.), and *C. hesperidum*, and is credited with controlling heavy infestations of *Saissetia nigra* on native vegetation in the vicinity of Los Angeles.

DESCRIPTION.—*Metaphycus helvolus* was described by Compere (1926) from 19 females and 11 males reared from host material collected in and near Cape Town, Union of South Africa, in July, 1924, by E. W. Rust, who sent the material to Riverside.

The most convenient characteristics for distinguishing *Metaphycus helvolus* from other species of parasites in the field are its small size (length, 1 mm.) and the difference in color of the sexes—the orange yellow of the female and the dark brown of the male. *M. helvolus* is most likely to be confused with *M. luteolus*, a closely allied species of similar habits but of a lemon-yellow color in both sexes.

HOST-PARASITE RELATIONS.—*Metaphycus helvolus* is endoparasitic and usually solitary; that is, but one individual develops, as a rule, in an individual host. One black scale, however, collected on a lemon tree near Ventura, California, yielded three large females of *M. helvolus*.

The adult female of *Metaphycus helvolus* is predaceous in habit: it feeds regularly on the body fluids of the scale. Feeding on host fluids follows the deposition of one or more eggs (usually from 1 to 5). This habit, in association with the extraordinarily long oviposition period of the parasite, complicates the mass propagation of the species. When excessive numbers of parasites are placed on a scale infestation consisting of small individuals, the feeding activity of the parasite adults is so destructive to the scale that reproduction of the parasites is prevented. Nevertheless, during a six-months' period in 1940, over 930,000 females of *M. helvolus* were produced in the insectary at the University of California Citrus Experiment Station.

When a female of *Metaphycus helvolus* contacts a host soon after having deposited several eggs, or after a prolonged absence of hosts, it exhibits the feeding reaction. In this operation the female stands upon the scale and, with its ovipositor, penetrates the derm centrally. Extensive and prolonged probing of the viscera of the scale follows, the ovipositor often being inserted its full length. At intervals, while its ovipositor remains inserted in the host, the female stops the probing motion and cleans its antennae and forelegs. Soon after the probing, the contents of the scale become pinkish in color.

The feeding operation is performed casually and is of longer duration than oviposition. In fact, the female may feed for several minutes at the wound made by its ovipositor. Before the nutritional needs of the female are satisfied, the feeding operation may be repeated several times in succession on different scales.

In ovipositing, only one egg is, as a rule, deposited in a host. This is inserted through the dorsum near either the anterior or posterior margins of the scale and is usually to be found in one of the anal lobes. The ovipositing female parasite takes a stance facing away from the scale, with only the ovipositor and hind tarsi touching the scale. With its ovipositor, it drills through the derm in 1 or 2 minutes. This operation is followed by a brief exploratory movement of the ovipositor. The female then remains more or less quiet during ovulation and deposition of the egg.

The egg emerges from near the tip of the ovipositor as a slender silvery filament which is the greatly constricted egg proper of the double-bodied egg (Fig. 2, *D*). When placed in position in the host, this filament suddenly expands with the inrush of its original contents plus the contents of the anterior bulb. The ovipositor is then carefully withdrawn, leaving the egg stalk projecting externally. The collapsed anterior bulb is apparently tucked into the lumen of the stalk as the ovipositor is withdrawn.

When newly emerged females are presented with scale, only probing activities occur, since the ovaries do not contain mature eggs (Fig. 1).

One 4-day-old unmated female, when first placed with scale, went through the ovipositing routine several times on one

scale without depositing an egg, then proceeded to feed on the same scale. The female was dissected immediately thereafter, and 4 fully formed eggs were found in the ovaries.

A 2-day-old mated female, when first presented with scale, performed the feeding routine on the first scale and then immediately oviposited in three scales in succession. On the fifth scale it performed the feeding routine again and on the sixth went through the ovipositing routine several times without ovipositing. The parasite was then isolated from the host for 24 hours. When again presented with scale, it oviposited immediately and then started the feeding routine on another scale, probing as usual through the middle of the dorsum. It withdrew, however, without feeding and oviposited near the margin. On the third scale it started to drill near the margin and then stopped. When dissected a few minutes later, this female was found to contain four fully formed eggs.

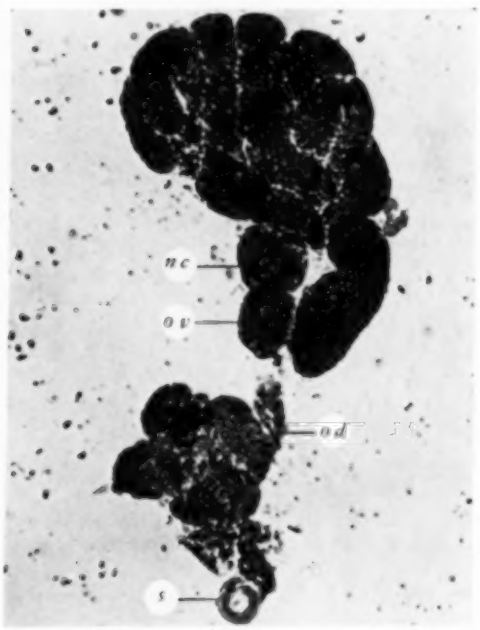

FIG. 1.—Ovaries of *Metaphycus helvolus* from newly emerged female, showing (*nc*) nurse cells, (*or*) developing egg, (*od*) oviduct, and (*s*) spermatheca.

The following sequence of activities was observed one day, between 9:00 A.M. and 4:00 P.M., with a 4-day-old mated female of *Metaphycus helvolus* that had, on the preceding day, deposited five eggs in hosts between feedings. In the first scale, three eggs were deposited in succession. In the second scale, the ovipositor was inserted near the margin, then in the center of the dorsum, again near the margin, and again in the center of the dorsum without depositing an egg. Oviposition occurred in the third and fourth scales. On the fifth scale, the female went through the feeding routine three times before actually feeding, keeping the wound open by reinsertion of the ovipositor. Two hours later, when presented with the sixth scale, it deposited two eggs, leaving the scale between depositions. Presented with the seventh scale, it began but did not complete the feeding routine and, instead, deposited two eggs. On the eighth scale, it went through the ovipositing routine three times without depositing an egg. It was then dissected, and four fully formed eggs were found in the ovaries.

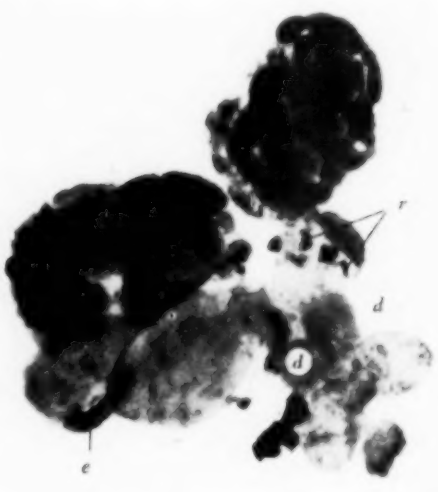

FIG. 2.—Ovaries of *Metaphycus helvolus* after cessation of oögenesis, showing (*e*) neck of double-bodied egg before absorption, (*d*, *d*) the paired oviducts, and (*r*) remnants of obsorbed eggs.

A comparative record of the daily egg production of eight mated females of *Metaphycus helvolus* is presented in table 1. Counts were made at the end of each 24-hour period. These females were given hosts continuously after emergence, as follows: Nos. 1, 3, 4, 8, after 2 days; No. 2, after 3 days; No. 5, after 23 days; and

Table 1.—Comparative record of eggs deposited daily by eight mated females of *Metaphycus helvolus* in their black-scale hosts[1] and estimated daily egg absorption[2] in females while withheld from hosts.

Age In Days	Eggs Deposited Daily by Parasite No.								
	1	2	3	4	5	6	7	8	9[2]
1									(0)
2									(0)
3	3		5	7				2	(3)
4	2	9	5	5				1	(3)
5	19	9	8	12			1[3]	9	(6)
6	7	12	8	17				12	(6)
7	12	11	17	12				9	(6)
8	11	1	5	15				7	(6)
9	7	11	4	7		2[3]		9	(6)
10	18	12	11	11				8	(3)
11	12	11	13	12				8	(3)
12	7	11	9	8				9	(0)
13	14	16	8	15				10	(3)
14	11	10	14	9				8	(0)
15	8	12	13	18				7	(3)
16	2	12	13	13				13	(0)
17	Died[4]	17	11	14				9	(3)
18		15	10	15				10	(0)
19		12	12	13				5	(1)
20		13	5	13				6	(0)
21		9	12	11				10	(0)
22		9	9	17				4	(0)
23		14	7	8				6	(0)[5]
24		11	9	11	0			6	
25		12	13	18	0			7	
26		15	15	12	1			14	
27		9	9	14	3			8	
28		11	6	13	2			13	
29		7	16	14	3	0	0	11	
30		7	8	11	1	0	0	10	
31		9	8	15	2	1	2	6	
32		12	6	2	13	2	2	2	
33		6	11	18	7	3	5	10	
34		13	9	10	10	10	8	3	
35		5	7	11	8	4	6	7	
36		7	8	13	9	12	15	6	
37		20	10	11	3	10	10	7	
38		7	9	8	11	6	11	4	
39		9	10	12	7	9	19	6	
40		8	8	15	7	4	10	5	
41		10	8	11	8	11	8	7	
42		9	11	15	7	9	15	7	
43		9	8	11	9	9	12	3	
44		6	11	17	3	9	3[6]	5	
45		11	11	6	11	15	5	6	
46		6	7	12	11	11	4	6	
47		5	5	12	6	9	15	0	
48		9	4	15	14	14	5	7	
49		9	1	9	10	12	5	6	
50		4	4	9	8	14	6	6	
51		10	4	11	5	8	3	6	
52		3	3	8	12	7	9	5	
53		8	3	5	9	12	4	3	
54		6	2	12	3	6	13	6	
55		8	2	9	6	16	9	4	
56		8	1	8	5	4	14	5	
57		6	4	10	2	9	5	5	
58		10	1	17	9	7	8	4	

Age In Days	Eggs Deposited Daily by Parasite No.								
	1	2	3	4	5	6	7	8	9[2]
59	muti-	lated	2	11	8	7	10	7	
60			1	8	2	2	10	3	
61			0	9	7	8	9	3	
62			Died[4]	13	4	8	1	2	
63				6	14	11	8	2	
64				9	3	6	8	6	
65				7	3	9	5	3	
66				8	8	13	10	6	
67				3	5	6	7	1	
68				4	10	7	4	5	
69				1	2	9	2	0	
70				Escaped	6	12	5	2	
71					6	6	4	2	
72					14	9	2	0	
73					3	4	4	0	
74					8	10	3	3	
75					4	1	2	1	
76					1	6	3	2	
77					3	7	2	1	
78					5	5	6	1	
79					Killed[7]	3	2	1	
80						7	Died[4]	0	
81						4		2	
82						2		5	
83						1		0	
84						Died[4]		0	
85								2	
86								0	
87								0	
88								0	
89								1	
90								0	
91								2	
92								0	
93								0	
94								Died[4]	
Total eggs deposited	133	531	454	738	341	408	339	441	(52)

[1] Females were given hosts continuously after emergence, as follows: nos. 1, 3, 4, and 8, after 2 days; no. 2, after 3 days; no. 5, after 23 days; and nos. 6 and 7, after 28 days. For description of procedure, see text, p. 692.

[2] The number of eggs absorbed is indicated in the table by figures in parentheses (parasite no. 9). Figures are averages based on number of mature eggs found in numerous females withheld from hosts and dissected at ages specified, based, also, on the fact that eggs are absorbed within 48 hours after reaching maturity. Note that no mature eggs were found after the 19th day.

[3] Eggs deposited when female was given host for several minutes only.

[4] Probably natural death; no eggs in ovaries.

[5] Oögenesis does not recommence until the female feeds on host fluids.

[6] Parasite injured; showed no signs of life for several hours; recovered later.

[7] Five mature eggs were found in ovaries of this female upon dissection.

Nos. 6 and 7, after 28 days. Each female was placed in a small glass vial in which about 20 scales were fastened by means of a thin streak of honey[1] and was transferred daily to a vial containing a fresh lot of scales. After the female had been transferred, the eggs deposited the preceding day were counted by means of the egg stalks protruding from the hosts. About 7000 scales were thus examined, and 3363 eggs were counted.

On the basis of daily records of oviposition, it was determined that, at a constant temperature of about 80° F., nine ovarian eggs reach maturity each day in the average host-fed female. One female which had been allowed to oviposit and feed on host fluids for 8 days was isolated for 24 hours and then dissected. In this female each ovary contained nine fully formed

[1] If the relative humidity is maintained at about 60 per cent, honey remains in good condition (Martin 1939) and, undiluted, is the ideal food for adult hymenopterous parasites.

eggs. In females that have not fed on host fluids and have not been allowed to oviposit, a maximum of three eggs per ovary may be found about a week after emergence.

In these studies, the maximum number of eggs deposited by one female was 740. The average number of eggs deposited per female was about 400. Since the food consumed during the larval period is not sufficient for the complete development of more than about 50 eggs, feeding on host fluids by the adult female is necessary for normal egg production. Females that were withheld from their host for a month at 80° F. deposited about three-fourths the number of eggs they would have deposited otherwise.

At a temperature of 80° F., females fed on honey only may live for 50 days, while those allowed to feed on host fluids may live twice that long. At outdoor temperatures (provided the insect is not exposed to the direct rays of the sun), the life of the adult female is greatly prolonged. One female, for example, which emerged October 7, 1940, lived until June 10, 1941. This female was brought into the laboratory and allowed to feed on host fluids on October 7 and November 10, 1940, and on January 22, February 26, March 31, and April 22, 1941.

The development of the eggs begins before the female emerges from its host, and a day-old female may deposit several eggs before feeding. When newly emerged mated females are withheld from their hosts for about three weeks, however, and are kept at a temperature of 80° F., they are unable to oviposit until 3 days after they have been placed with their hosts (see Table 1). This delay in oviposition is the result of the lack of mature eggs in the ovaries. The ovaries of such females contain only primary oögonia, and 3 days are required for complete development of the egg in the ovary.

In newly emerged females withheld from hosts, oösorption begins within 3 days after emergence. Since mature eggs are not present in the ovaries until the second day and remnants of absorbed eggs are present on the fourth day, it is evident that an egg can be absorbed in less than 48 hours after it is ripe.

Oösorption occurs likewise in *Metaphycus luteolus*, *M. lounsburyi* (Howard), and *M. stanleyi* Compere. In these species, however, oögenesis continues until the death of the female. In *M. helvolus* oögenesis ceases (Fig. 2) when the female is prevented from feeding on its host for about three weeks. In *M. luteolus*, which in form and habit is almost identical with *M. helvolus*, oögenesis does not cease when the insect is isolated from its host.

When a female of *Metaphycus helvolus*, which has been with suitable hosts continually, dies from some internal cause, the ovaries are found to be entirely depleted of eggs.

While the scale population is static, there is a marked pyramiding of the population of *Metaphycus helvolus*. This is brought about by the short life cycle of the parasite and the extended oviposition period of long-lived females.

The larva of *Metaphycus helvolus* develops only in the second and early third instars of black scale, although the adult female may feed on the fluids of all instars. Adult parasites have emerged from scales ranging in length from 0.8 to 1.8 mm. Usually 1, occasionally 2, and rarely 3 parasites complete development in a single scale. The entire fluid contents of the host are consumed, and the derm becomes dry and brittle and light brown in color. There is no indication of melanization or darkening of the derm of the host, however. Before the host fluids are completely consumed, the parasite larva constructs a membranous cocoon which is inflated with air through connection with the tracheae of the host. When more than one larva is present, the interior of the scale is divided into compartments by means of the cocoons.

Under insectary conditions, when the scales are uniform in age, two generations of *Metaphycus helvolus* may develop on one generation of scale. Under field conditions, when the scales vary widely in age, the number of generations of *M. helvolus* to one of scale may exceed eight. A life cycle of 15 days has been observed at outdoor temperatures during July, August, and September. The reproduction of this parasite is therefore rapid.

In the insectary, at a temperature of approximately 82° F., the life cycle of *Metaphycus helvolus* is 13 days. The incubation of the egg requires 3 days; the first three instars, 2 days; the fourth instar (including the prepupal period), 2 days;

and the pupal period, 6 days. The male completes its pupal development in less time than the female. Unfertilized eggs always produce males. The sex ratio of the progeny of mated females is determined largely by the frequency of oviposition and the preferential character of the host individuals (Flanders 1939).

The immature stage of *Metaphycus helvolus* are typically encyrtid in structure: The egg is stalked and possesses a complete aeroscopic plate to which the larva appresses its anal spiracles. Each of the first three instars possesses two pairs of caudal spiracles. (This seems to be characteristic of the genus. Some other encyrtids with caudal spiracles have only one pair.) The fourth instar possesses the typical nine pairs of spiracles.

Mating takes place immediately after emergence. The female does not oviposit until the following day. Reproductive activity may occur when air temperatures are about 49° F., particularly if the females are exposed to sunlight. Observations reported by Holloway[1] show that if the parasites are exposed to radiant energy, they maintain normal activity when the surrounding air temperatures are a few degrees below that required for such activity.

Metaphycus helvolus appears to do its most effective work during the fall and winter months.

COMPARATIVE STUDIES.—Since *Metaphycus helvolus* is the most effective of the black-scale parasites in California it must possess one or more unique abilities. These are most clearly shown by comparing this parasite with others such as *Coccophagus trifasciatus* Compere and *M. lounsburyi*.

Observations by Rust (Smith & Compere 1926) and by Compere (1940) on the relative abundance of black-scale parasites in Africa indicated that *Coccophagus trifasciatus* was the most promising as a control of the scale in California. Because it oviposited in scales showing a wide range in size, it seemed to be particularly promising for even-hatch areas (Smith 1921). In 1924 this parasite was successfully established on black scale in the vicinity of Riverside, but failed completely to accomplish the purpose for which it was introduced. This failure may have been due to the lack of a host suitable for the development of the hyperparasitic males. Males of *C. trifasciatus* can apparently develop only on the female larvae of parasites the males of which are ectoparasitic hyperparasites like those of *C. cowperi* Girault. *C. lycimnia* Walker is such a parasite, but it normally inhabits lecaniine scales other than black scale. Where there is a mixed population of scales, as in White Park, Riverside, *C. trifasciatus* may reproduce in large numbers on black scale. But even with an abundance of scales available, it is unlikely that *C. trifasciatus* would be capable of controlling black scale satisfactorily, since the life of the individual parasite is very brief and its searching power is accordingly limited.

In 1919 the parasite *Metaphycus lounsburyi* was established in southern California. It reproduced rapidly and within a year or two had brought large infestations of black scale under control. Subsequently, however, heavy reinfestation occurred. *M. lounsburyi* was not completely effective, partly because it brought about a uniformity in the condition of the scale, which interrupted the reproduction of the parasite by causing long periods when there was a scarcity of suitable hosts. The longevity of females of *M. lounsburyi* is not sufficient to enable them to bridge the gap between their emergence and the occurrence of scales of the next generation large enough for parasitization, when the host brood is even in development. Because of its large size, its gregarious habit, and its longer developmental period, *M. lounsburyi* is also more susceptible to hyperparasitic attack than either *M. helvolus* or *Coccophagus trifasciatus*.

Although both *Coccophagus trifasciatus* and *Metaphycus lounsburyi* are able to reproduce more effectively in the presence of ants than is *M. helvolus*, they are less effective at low host population levels.

Coccophagus trifasciatus has been observed to deposit one egg per host at the rate of 1 egg per second. *Metaphycus helvolus* requires several minutes to deposit an egg. *C. trifasciatus* is the equal of *M. helvolus* in egg-producing ability, but when ovipositing to full capacity, at 80° F., *C. trifasciatus* must deposit most of its eggs within 3 days after emergence. This is in marked contrast to *M. helvolus*, which oviposits over a period of three months.

[1] Holloway, J. K., in a letter to author dated February 4, 1937.

The maximum number of eggs deposited during one day by *C. trifasciatus* was 240; that by *M. helvolus*, 20.

At a temperature of 80° F., the nonovipositing females of *Coccophagus trifasciatus* live about 2 weeks, twice as long as the ovipositing females. In the case of *Metaphycus helvolus*, however, the ovipositing, females may live 3 months, twice as long as the nonovipositing, non-host-feeding females. If fed on honey and, occasionally, on host fluids, nonovipositing females of *M. helvolus* may live 3 months at summer temperatures and 8 months at winter temperatures. When the females of *C. trifasciatus* and of *M. helvolus* are allowed to oviposit continuously at 80°, those of *M. helvolus* live over twelve times as long as those of *C. trifasciatus*. When oviposition and host-feeding are prevented, females of *M. helvolus* live only three times as long as those of *C. trifasciatus*.

The adult female of *Metaphycus helvolus* not only lives longer than that of either *M. lounsburyi* or *Coccophagus trifasciatus*, but also develops to an adult in a shorter time. Restriction of development to a certain period of scale development is therefore not the handicap that it is in the case of *M. lounsburyi*. *C. trifasciatus* has the advantage over other parasites of the black scale in being able to develop in late third-instar as well as in second-instar scales.

The effectiveness of *Metaphycus helvolus* tends to be greater than that of either *Coccophagus trifasciatus* or *M. lounsburyi* because none of the scales parasitized by *M. helvolus* produce offspring. This is not always the case with scales parasitized by *C. trifasciatus* and *M. lounsburyi*. Although *M. helvolus* develops in more scales otherwise destined to die without progeny than does *M. lounsburyi*, this is an advantage, since the rate of reproduction and the number of parasites early in the susceptible period of host development are thus increased. Successful host searching by *M. helvolus* is assured by the long period of host vulnerability during the second and early third stages of host development. (In the even-hatch areas of California, the black scale is susceptible to attack from July to March.)

The feeding habit of the adult female of *Metaphycus helvolus* (see 'Host-Parasite Relations," p. 691) enables it to generate a large number of eggs over a long period of time. Since these eggs are, as a rule, deposited 1 per host, they are used more efficiently than those of *M. lounsburyi*, which deposits about three eggs in each host. Apparently, *M. helvolus* is able to reproduce at host densities so low that its own density is too low for the reproduction of secondary parasites. When the host is scarce, *M. helvolus* may destroy more scale by adult feeding than by oviposition. Chances of superparasitism at low host densities are thus decreased by the host-feeding habit of this parasite, since the female is likely to feed on isolated hosts instead of ovipositing.

THE EFFECT OF INSECTICIDES ON *Metaphycus Helvolus*.—Insecticides have a detrimental effect on the reproduction of *Metaphycus helvolus*, either by repelling the host-searching females, by the reduction of the food supply of the parasite or by the destruction of the adult parasites when there is a scarcity of hosts harboring the immature stages.

In general, parasites of black scale thrive best when the scale is in all stages of development at all times. Anything that brings about an even-hatch condition of the scale affects the reproduction of the parasites adversely, since they are limited in their attack to certain stages of the scale.

The application of insecticides for the control of other pests should be so timed that the parasites of the black scale are least affected. In the case of *Metaphycus helvolus*, such treatment should occur when the black scale harbors the immature stages of the parasite in greatest numbers.

In the laboratory and in the field it has been demonstrated that contact with particles of sulphur paralyzes the adults of *Metaphycus helvolus* and *M. luteolus* and is consequently lethal. Extensive applications of sulphur dust in the field have been followed by outbreaks of black scale and soft (brown) scale.

SUMMARY.—*Metaphycus helvolus* (Compere), an encyrtid parasite of lecaniine scales, has been observed in relation to the black scale, *Saissetia oleae* (Bern.).

The importance of *Metaphycus helvolus* in the control of the black scale in South Africa was obscured by the influence of the Argentine ant on the relative abundance

of the parasites of this scale. Since the establishment of *M. helvolus* in California in 1937, it has become a dominant factor in the reduction of the black scale over wide areas.

The effectiveness of *Metaphycus helvolus* is, in part, an effect of the predatory habits of the female adult, its exceptionally long oviposition period, short life cycle, and its solitary parasitization of the stages of the host having the longest period of exposure.

Metaphycus helvolus, *Coccophagus trifasciatus* Compere, and *M. lounsburyi* (How.) are compared as to certain biological characteristics.

Insecticides tend to decrease the effectiveness of *Metaphycus helvolus*, directly, by destroying the female adults at a time when there is a scarcity of hosts harboring the immature parasites or, indirectly, by bringing about an even-hatch condition of the host generations so that there is a lack of food for the parasites.—4-22-24.

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Effect of Dormant Sprays on Parasites of the San Jose and Terrapin Scales

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The toxicity of dormant insecticides to scale insects of fruit trees has been studied by a number of investigators but comparatively little attention has been given to the effects of these sprays on the parasites. Hodgkiss & Parrott (1914) found that the continued use of lime-sulphur for a number of years in apple orchards reduced the parasitism of the San Jose scale. Rice (1937) observed that a heavy infestation of San Jose scale on unsprayed apple trees was brought under control within a few months by the parasites.

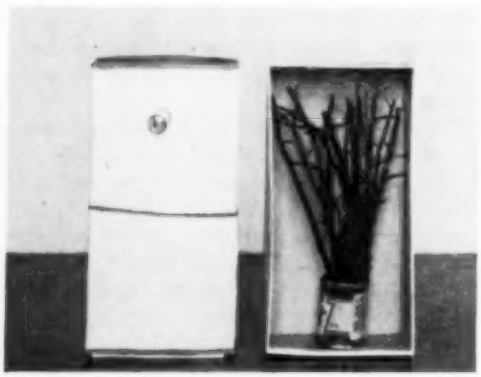

FIG. 1.—Cages used in rearing parasites of scale insects.

Since it is a general practice to make annual applications of dormant sprays to commercial orchards, the writer became interested in the effects of these sprays on the parasites of scale insects. In 1937 investigations were started to determine the effects of these sprays on the parasites of San Jose scale, *Aspidiotus perniciosus* Comstock, and terrapin scale, *Lecanium nigrofasciatum* Pergande.

Early in the work a decided difference was noted in the number of parasites that emerged from infested twigs collected from sprayed and unsprayed trees. This paper gives a report of the experiments and points out some of the problems that deserve consideration in future studies.

METHODS AND MATERIALS.—Scale insects were collected in the spring by cutting twigs 8 to 10 inches long from infested host plants. The infested twigs were brought into the insectary and divided into lots. For spraying, the infested twigs were placed in holes on a revolving disc. Spraying was accomplished by means of an air compressor, such as is used in paint spray outfits, and a home-made nozzle which delivered a fine mist at 30 pounds pressure.

Dinitro-o-cyclo-hexylphenol was used in two types of mixtures; namely, a dry-mix consisting of the toxic material mixed with other ingredients and the toxic material dissolved in petroleum oil. The oil preparation is marketed under the name *Dowspray Dormant* and was emulsified by the use of a special emulsifier manufactured by the Dow Chemical Company. The dry-mix preparations were added to the oils after they were emulsified.

Table 1.—Emergence of parasites from San Jose scale on apple twigs sprayed with dormant insecticides.[1]

MATERIALS AND RATE PER 100 GALLONS	EMERGENCE OF PARASITES			
	1938	1939	1940	1941
Oil,[2] 3%, tar distillate 2½%	None	None	None	None
Dowspray Dormant 2%	do	do	do	do
Oil,[3] 3%	do	—	—	—
Petroleum oil (135 seconds viscosity) 2%, Dry-mix (D-23) 1.75 pounds (DNOCHP 7.5 ounces)	do	None	None	None
Petroleum oil (135 seconds viscosity) 3% Dry mix 1.75 pounds (DNOCHP 9.8 ounces)	do	do	do	do
Lime sulphur (26° Baumé) 15 gallons	—	7 parasites emerged	do	do
Petroleum oil (166 seconds viscosity) 3%	—	1 parasite emerged	None	None
Nitro-Kleenup 3%	—	1 parasite emerged	do	do
Nitrocide 3%	—	None	do	do
Elgetol 1%	—	1 parasite emerged	do	do
Check	Many parasites of 3 species emerged	Many parasites of 3 species emerged	Many parasites of 2 species emerged	Many parasites of 5 species emerged

[1] Date sprays were applied: 1938, March 3; 1939, March 8; 1940, March 29; 1941, March 27.
[2] Prepared from an emulsion containing 46.5% petroleum oil and 38.5% tar oil (creosote oil).
[3] Prepared from an emulsion containing 83% petroleum oil.

After the twigs were sprayed, they were allowed to dry and were placed in shoe-box cages (Fig. 1). The twigs were kept in a small quantity of water before and after spraying to prevent drying out.

Glass vials were fitted in the sides of the cages for the emergence of the parasites. The cages were kept in an outdoor insectary.

The petroleum oils used consisted of a ready-mix 83 per cent oil emulsion and two unemulsified oils with viscosities of 135 and 166 seconds Saybolt, respectively, at 100° F. The unemulsified oils were emulsified by the use of 4 ounces of *Goulac* and 12 ounces of bentonite per 100 gallons of diluted spray. The combination of petroleum oil and tar oil emulsion contained 46.5 per cent petroleum oil and 38.5 per cent tar oil.

The following commercial preparations were used: *Elgetol*, a dinitro product which contains a sodium salt of dinitro-cresol; *Nitro-Kleenup*, an oil emulsion containing dinitro-phenol; and *Nitrocide*, an oil emulsion containing a toxicant which is said to be a mixture of trinitro-phenol and trinitro-toluene. Dormant strength lime-sulphur was used in some of the tests.

EXPERIMENTS AND RESULTS.—In the spring of 1937, two lots of hawthorn twigs, heavily infested with terrapin scale, were collected; one lot was sprayed with a 6 per cent petroleum oil (135 seconds viscosity) and the other was not sprayed. Both lots were placed in shoe-box cages in the insectary. No parasites emerged from the sprayed twigs, whereas many individuals of seven species of parasites emerged from the unsprayed twigs.

Table 2.—Emergence of parasites from terrapin scale on peach and hawthorn twigs sprayed with dormant insecticides.[1]

Materials and Rate per 100 Gallons	Emergence of Parasites			
	1938	1939	1940	1941
Oil[2] 3%, tar distillate 2½%	—	None	None	None
Dowspray Dormant 2%	—	do	do	do
Oil[3] 3%	None	—	—	—
Petroleum oil (135 seconds viscosity) 3%, Drymix 1.75 pounds (DNOCHP 9.8 ounces)	do	—	—	—
Petroleum oil (135 seconds viscosity) 2%, Drymix (D-23) 1.75 pounds (DNOCHP 7.5 ounces)	do	—	—	—
Petroleum oil (166 seconds viscosity) 4%	—	1 parasite emerged	None	None
Nitro-Kleenup 3%	—	None	do	do
Nitrocide 3%	—	do	do	do
Elgetol 1%	—	do	do	do
Lime-sulphur (26° Baumé) 15 gallons	—	1 parasite emerged	do	do
Check	Many parasites of 7 species emerged	Many parasites of 4 species emerged	Many parasites of 6 species emerged	Many parasites of 9 species emerged

[1] Date sprays were applied: 1938, March 3; 1939, March 8; 1940, March 29; 1941, March 27.
[2] Prepared from an emulsion containing 46.5% petroleum oil and 38.5% tar oil (creosote oil).
[3] Prepared from an emulsion containing 83% petroleum oil.

During the seasons of 1938 to 1941 twigs infested with the San Jose and terrapin scales were sprayed with a number of of dormant insecticides. A list of the materials as well as the results are shown in tables 1 and 2. It is not necessary to discuss the results of the various tests except to point out that no parasites emerged from the sprayed twigs, except in 1939 when a few parasites emerged from some of the sprayed twigs; whereas a large number of individuals of several species of parasites emerged from the unsprayed twigs. The emergence of parasites from sprayed twigs may be due to a number of factors, such as poor coverage or the failure of some of the advanced stages of the parasites to be killed by the sprays. During this study very little information was obtained from field tests. In 1939 a heavy infestation of San Jose scale was found in a commercial apple orchard. Twigs infested with scales were collected from trees before and after they were sprayed with a 4 per cent petroleum oil. No parasites emerged from the sprayed twigs; whereas several individuals belonging to the species *Prospaltella perniciosus* Tower emerged from the unsprayed twigs.

No attempt was made to determine the percentage of parasitism of scales on the various lots of twigs, except that during the season of 1941 a check was made on the parasitism of those on the unsprayed twigs. The San Jose scale was 41 per cent parasitized and the terrapin scale was 40 per cent parasitized.

From 1937 to 1941 the following species[1] of parasites emerged from the San Jose and terrapin scales:

From San Jose scale.—

Prospaltella perniciosus (Tower)
Prospaltella diaspidicola (Silv.)
Physcus varicornis (How.)
Marietta carnesi (How.)
Anagrus epos (Gir.)
Aphytis mytilaspidis (Le Baron)

From terrapin scale.—

Coccophagus fuscipes (How.)
Coccophagus lycimnia (Walk.)
Physcus varicornis (How.)
Cheiloneurinus microphagus (Mayr.)
Thysanus pulchra (Gir.)
Marietta mexicana (How.)
Tetrastichus belpyri (Ashm.)
Aphycus stomachosus (Gir.)
Aphycus sp.
Asteropaeus sp. near primus (How.)

Discussion.—There are some questions that can only be answered by more comprehensive study. Can the sprays be timed so as to promote an increase in the parasite population? According to Tower (1914) and Rice (1937) *Prospaltella perniciosus* Tower, the most important parasite of the San Jose scale, overwinters in the egg, first and third larval stage and

[1] Determined by the U.S.D.A. Bureau of Entomology and Plant Quarantine, Division of Insect Identification.

pupal stage. Dissections of San Jose and terrapin scales at the time the dormant sprays were applied showed parasites in the immature, and full-grown larval stage and in the pupal stage.

There can be little doubt that dormant sprays that are fatal to the host would also destroy the immature stages of the parasite, either by direct action of the insecticides or because of the unsuitability of a dead host for completion of its growth. Some of the full-grown larvae and pupae may escape the harmful effects of the sprays, as a few parasites are usually present in sprayed orchards.

There is also need for information on the effect of the general use of arsenical and non-arsenical sprays on the population of the parasites. From the information we have, apparently the present spray practices have a tendency to reduce the parasites in sprayed orchards. However, we should keep in mind that even though the spray practices were modified, we have little data to prove that the parasites would increase in sufficient numbers to control scale insects in commercial orchards.

SUMMARY.—In the laboratory, insecticides commonly used in dormant sprays for orchard pests, were quite toxic to parasites of the San Jose and terrapin scales. The following species of parasites were reared: From the San Jose scale—*Prospaltella perniciosus* Tower, *P. diaspidicola* Silv., *Physcus varicornis* How., *Marietta carnesi* How., *Anagrus epos* Gir., *Aphytis mytilaspidis* Le Baron. From the terrapin scale—*Coccophagus fuscipes* How., *C. lycimnia* Walk., *Physcus varicornis* How., *Cheiloneurinus microphagus* Mayr; *Thysanus pulchra* Gir., *Marietta mexicana* How., *Tetrastichus belpyri* Ashm., *Aphycus stomachosus* Gir., *Aphycus* sp., *Asteropaeus* sp. Two questions that can only be answered by more comprehensive information are: (1) Can the sprays be timed so as to promote an increase in the parasite population? (2) What effect does the general use of arsenical and non-arsenical sprays have on the population of the parasites? From the information we have, apparently the present spray practices have a tendency to reduce the parasites in sprayed orchards. —5-13-42.

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A FURTHER NOTE ON WOOD-BORING BY THE DRUGSTORE BEETLE

Since the publication in the current volume of this JOURNAL (p. 452) of a record of injury to bamboo mah-jongg playing pieces by the drugstore beetle, an additional instance of wood-boring by this insect has been called to the attention of the writer by Dr. A. E. Michelbacher. In May, 1942, the species was responsible for extensive injury to thin wooden forms in a private home in San Francisco. Although there is a possibility that the forms may have been contaminated with flour or some other food material and thus been made attractive to the beetles, the facts are that the wood itself was riddled in typical anobiid fashion, resembling the work of a death watch beetle. The pellets of wood which filled the burrows were suggestive of those of the California death watch beetle, *Hadrobregmus gibbicollis* LeConte. Mr. W. S. Fisher, of the Division of Insect Identification, Bureau of Entomology and Plant Quarantine, has very kindly confirmed the identification of specimens reared from these forms, as well as those upon which the previous record was based, as the drugstore beetle, *Stegobium paniceum* (Linn.). 10-21-42.

E. GORTON LINSLEY, *University of California, Berkeley.*

The Influence of Insecticides Added to Soils on Growth and Yield of Certain Plants[3]

DAVID B. SCOTT, JR.[1] and ERROL HAY KARR,[1,2] *Tacoma, Wash.*

With the ever increasing use of various chemicals for the control of insect pests on agricultural crops, there is an evident need for additional information regarding the effect on plant growth of accumulated quantities of these materials in the soil. Inasmuch as it has been demonstrated that most plants derive their sustenance from the surface soil, Millar (1925) and Salter (1940), it is also of importance that insecticidal residues tend to accumulate in the surface soil horizon as stated by Vandecaveye, *et al.* (1936), Jones & Hatch (1937), and Vandecaveye *et al.* (1938).

Over a period of years, the extent to which the soil becomes impregnated with insecticides depends upon the climate, soil texture and chemical composition, and frequency of insecticide application. It was the purpose of this investigation to cover a range of concentrations of insecticide in soil generally above that found in the field (with a few exceptions) in order to observe the immediate effect of initial high concentrations comparable to those that might accumulate without change after continued use of the same compounds for insect control.

Though investigations by Wöber (1920), Cristiani (1927), Bartholomew (1935), and Morse (1935), have shown that soluble fluorides have decidedly deterimental effects upon plant growth, the effect of less soluble fluorides has been limited principally to tests with calcium fluoride. The Arkansas Experiment Station (1934), Morse (1935), and MacIntire *et al.* (1935) found this latter compound to be nontoxic to plant life, even when present in very high concentrations in the soil.

The work of Morris (1927), Crafts (1939), Dorman *et al.*, (1939), and many others has shown that small amounts of certain arsenic compounds are very toxic to soils. The arsenical preparations used in these investigations are extensively employed as insecticides and were included for comparing their toxicity in soil with that of natural cryolite under identical conditions. Marcovitch *et al.* (1937) say that "The continued use of arsenic for the control of insect pests, in many instances, results in soil poisoning. On the sandy soils of South Carolina, for example, dusting with calcium arsenate for the control of the boll weevil has made the soil unfit for cowpeas." Vandecaveye *et al.* (1936) suggest a similar situation which is becoming increasingly evident in the Pacific Northwest and other sections of the country.

Since the scope of this paper is limited to one year, there are obviously several gaps which can be filled only by further investigation: the time factor in relation to fluorine conversion over a period of years, the comparative fluorine and arsenic intake of the plant tissues and fruit, and the ultimate effect of natural cryolite upon the calcium balance of the soil. Further work would also be necessary to verify the effects upon other species of plants.

MATERIALS AND METHODS.—Two representative virgin soils, a clay loam and a sandy loam, both secured near Wenatchee, Washington, were used in the experiment which was conducted in Wenatchee during 1940. Special boxes, constructed of clear douglas fir, were used to hold the soil. The inside dimensions of the boxes were 14 inches long, 11 inches wide, and 11.5 inches deep to give a capacity of slightly more than 1 cubic foot. The bottom of each gox was fitted with a drain opening.

Natural cryolite, standard lead arsenate, and calcium arsenate are represented in the experiment. The natural cryolite used was the product which is specially prepared for insecticidal uses by the micronizing process. The greater proportion of the insecticide is composed of particles having over-all dimensions of 5 microns or less and contains at least 90 per cent sodium fluoaluminate, Underwood (1935). Natural cryolite is only slightly soluble in water. The product is being widely used for codling moth sprays

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[2] The authors wish to acknowledge the assistance of J. E. Underwood, manager of the Development and Research Department of the Pennsylvania Salt Manufacturing Company, who read and criticized the manuscript.

[3] Early publication of this paper has been secured by the payment of the printing charges.

and for the control of many other chewing pests on citrus and truck crops. The standard lead arsenate used was one of the well known brands marketed for codling moth control on apples and pears and was guaranteed to contain 96 per cent di-lead arsenate. The third insecticide employed was a standard brand of calcium arsenate used for potato dusting and with a guaranteed analysis of 70 per cent tricalcium arsenate.

One-cubic foot aliquots of the two soil types were treated to contain zero, 500, 1500, and 3000 pounds per foot-acre of one of the three insecticides used. This series arrangement was followed for the two crops employed in the experiment. For accuracy and convenience, only 1 cubic foot of soil, or enough for one box, was treated at a time. The mixing was accomplished by rolling the soil and the added insecticide in a barrel mixer for two hours.

To secure an approximate cross section of a number of important truck crops, many of which belong either to the family Solanaceae or to the family Leguminoseae, two species were selected that are known to be susceptible to chemical injury from soil sources. Bush lima beans were chosen from the leguminous group and bell peppers from the solanaceous group.

Twelve lima bean seeds were planted in each soil type and insecticide concentration, which made a total of 20 boxes. Twenty-eight bell pepper seeds were planted in each of another 20 boxes containing the varying insecticide concentrations and soil types. After the seedlings were an inch or so in height, the plants were thinned to four well spaced plants per box.

The soil pH before and after the experiments was taken with a La Motte-Morgan soil testing set. The soil pH samples at the beginning of the tests were taken at random in the respective boxes whereas samples for the final pH tests were secured 2 inches below the surface to avoid interference by molds or algae. The two readings were averaged for the mean pH, tables 1 to 4 inclusive, in order that an excessive change would be detected if it occurred.

SOIL ANALYSIS.—Soil samples for arsenic trioxide and fluorine determinations were taken at random at various depths and locations in the boxes before and after the experiments. The soils to which lead arsenate and calcium arsenate had been added were analyzed for water soluble arsenic trioxide and total arsenic trioxide. Natural cryolite-treated soils were analyzed for water soluble fluorine and total fluorine. To secure the most accurate and consistent results, the procedures employed for the determination of arsenic and fluorine in the soil had been previously checked and compared with several other recognized methods. The amounts of arsenic or fluorine found were calculated as parts per million of the air-dry soil.

To determine the amount of water-soluble arsenic trioxide or water-soluble fluorine in the samples, 75 grams of the soil were placed in erlenmeyer flasks together with 500 milliliters of water. The

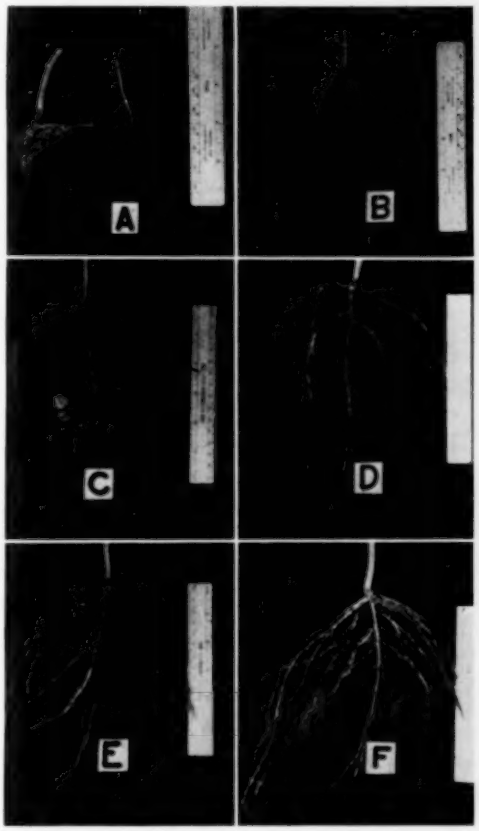

FIG. 1.—Roots of Lima Beans in Clay Loam
A. 500 lbs. per foot acre of lead arsenate
B. 500 lbs. per foot acre of calcium arsenate
C. 500 lbs. per foot acre of natural cryolite
D. 1500 lbs. per foot acre of natural cryolite
E. 3000 lbs. per foot acre of natural cryolite
F. Control

Table 1.—Growth and Yield of Lima Beans in Clay Loam

Insecticide Added to Soil	Am't. of Insecticide Added. Lbs./Ft. Acre	F_2 in soil—by Analysis p.p.m.				As_2O_3 in soil—by Analysis p.p.m.				Mean pH of Soil	Maximum Growth of Plants Ave. of 4 (Ht. in inches)	Mean Yield per Plant Ave. of 4 (Grams)	Dry Wt. of Plants Ave. of 4 (grams)
		at start		at end		at start		at end					
		Total	Water sol.	Total	Water sol.	Total	Water sol.	Total	Water sol.				
Control	Nothing added	145	1	145	less than 1	0	0	0	0	7.6	26.48	37	13.0
Natural Cryolite	500	230	36	190	11	—	—	—	—	7.7	18.31	60	9.9
	1500	360	120	320	80	—	—	—	—	7.7	24.44	51	10.8
	3000	600	171	590	118	—	—	—	—	7.3	21.06	53	10.9
Lead Arsenate	500	—	—	—	—	25	8	25	7	7.5	4.97	9	2.1
	1500	—	—	—	—	136	30	132	28	7.5	Seeds died	0	—
	3000	—	—	—	—	266	64	251	43	7.7	Seeds died	0	—
Calcium Arsenate	500	—	—	—	—	37	3	28	2	7.7	4.79	24	3.7
	1500	—	—	—	—	149	5	132	5	7.7	Seeds died	0	—
	3000	—	—	—	—	330	14	341	10	7.5	Seeds died	0	—

Table 2.—Growth and Yield of Lima Beans in Sandy Loam

Insecticide Added to Soil	Am't. of Insecticide Added Lbs./Ft. Acre	F_2 in Soil—by Analysis p.p.m.				As_2O_3 in Soil—by Analysis p.p.m.				Mean pH of Soil	Maximum Growth of Plants Ave. of 4 (Ht. in Inches)	Mean Yield Per Plant Ave. of 4 (Grams)	Dry Wt. of Plants Ave. of 4 (grams)
		at start		at end		at start		at end					
		Total	Water sol.	Total	Water sol.	Total	Water sol.	Total	Water sol.				
Control	Nothing added	195	2	195	less than 1	0	0	0	0	7.4	31.62	93	13.4
Natural Cryolite	500	265	49	210	15	—	—	—	—	7.4	22.95	68	9.6
	1500	415	104	380	62	—	—	—	—	7.1	20.31	74	12.2
	3000	640	252	620	217	—	—	—	—	7.3	18.22	53	11.1
Lead Arsenate	500	—	—	—	—	18	10	8	7	7.5	Seeds died	0	0
	1500	—	—	—	—	101	38	91	25	7.1	Seeds died	0	0
	3000	—	—	—	—	225	74	216	52	6.9	Seeds died	0	0
Calcium Arsenate	500	—	—	—	—	24	7	18	5	6.9	Seeds died	0	0
	1500	—	—	—	—	146	37	125	7	6.9	Seeds died	0	0
	3000	—	—	—	—	285	30	284	19	7.0	Seeds died	0	0

Table 3.—Growth and Yield of Bell Peppers in Clay Loam

Insecticides Added to Soil	Am't. of Insecticide Added Lbs./Ft. Acre	F_2 in Soil—by Analysis p.p.m.				As_2O_3 in Soil—by Analysis p.p.m.				Mean pH of Soil	Maximum Growth of Plants Ave. of 4 (Ht. in Inches)	Mean Yield Per Plant Ave. of 4 (Grams)	Dry Wt. of Plant Ave. of 4 (Grams)
		at start		at end		at start		at end					
		Total	Water sol.	Total	Water sol.	Total	Water sol.	Total	Water sol.				
Control	Nothing added	145	1	145	less than 1	0	0	0	0	7.6	32.97	95	18.6
Natural Cryolite	500	230	36	190	11	—	—	—	—	7.8	25.36	71	13.3
	1500	360	120	320	80	—	—	—	—	7.7	26.44	36	11.0
	3000	600	171	590	118	—	—	—	—	7.3	20.81	96	11.2
Lead Arsenate	500	—	—	—	—	25	8	25	7	8.5	18.34	50	8.6
	1500	—	—	—	—	136	30	132	28	7.6	12.87	21	3.4
	3000	—	—	—	—	266	64	251	43	7.7	Plants died	0	0
Calcium Arsenate	500	—	—	—	—	37	3	28	2	7.7	25.17	92	13.6
	1500	—	—	—	—	149	5	132	5	7.4	18.99	44	6.8
	3000	—	—	—	—	350	14	341	10	7.5	13.62	26	4.7

Table 4.—Growth and Yield of Bell Peppers in Sandy Loam

Insecticides Added to Soil	Am't. of Insecticide Added lbs./ft. Acre	F_2 in Soil—by Analysis p.p.m.				As_2O_5 in Soil—by Analysis p.p.m.				Mean pH of Soil	Maximum Growth of Plants Ave. of 4 (Ht. in Inches)	Mean Yield Per Plant Ave. of 4 (Grams)	Dry Wt. of Plants Ave. of 4 (Grams)
		at start		at end		at start		at end					
		Total	Water sol.	Total	Water sol.	Total	Water sol.	Total	Water sol.				
Control	Nothing added	195	2	195	less than 1	0	0	0	0	7.4	36.34	113	19.9
Natural Cryolite	500	265	49	210	15	—	—	—	—	7.4	24.94	47	10.6
	1500	415	104	380	62	—	—	—	—	7.1	21.00	127	13.2
	3000	640	232	620	217	—	—	—	—	7.3	27.16	87	15.9
Lead Arsenate	500	—	—	—	—	18	10	8	7	7.5	34.50	51	10.8
	1500	—	—	—	—	101	38	91	25	7.1	15.03	40	5.5
	3000	—	—	—	—	225	74	216	52	6.9	4.62	0	.48
Calcium Arsenate	500	—	—	—	—	24	7	18	5	6.9	26.00	113	17.8
	1500	—	—	—	—	146	37	125	7	6.9	22.34	100	11.7
	3000	—	—	—	—	285	50	284	19	7.0	14.50	37	5.2

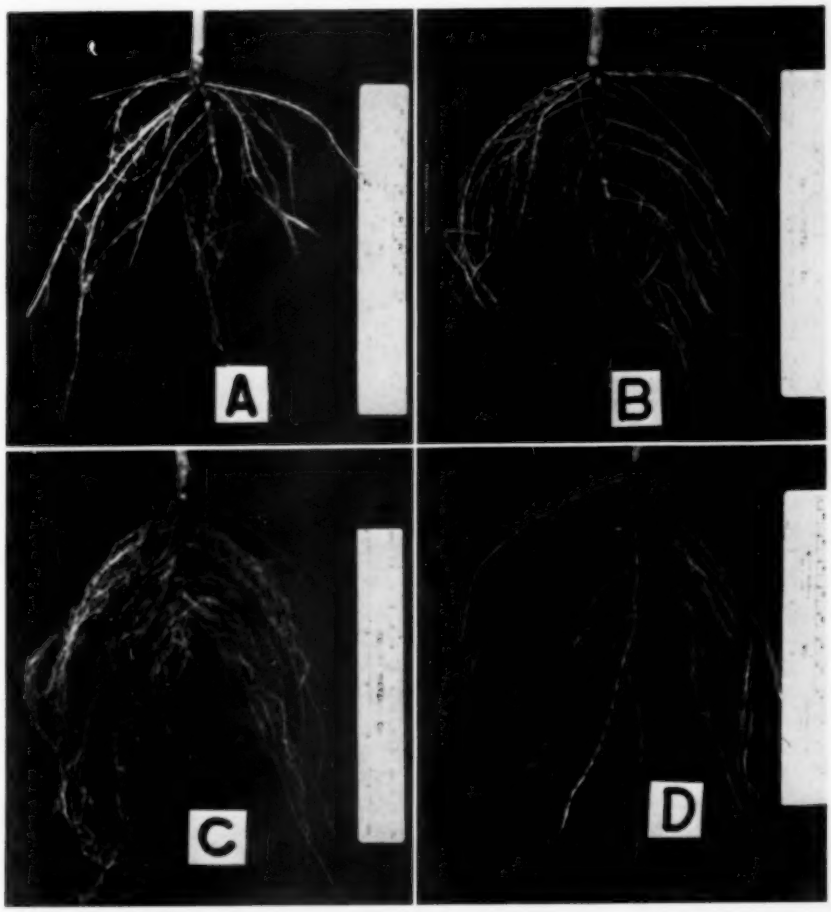

FIG. 2.—Roots of Lima beans in Sandy Loam

A. 500 lbs. per foot acre of natural cryolite
B. 1500 lbs. per foot acre of natural cryolite
C. 3000 lbs per foot acre of natural cryolite
D. Control

Note: Roots of lima beans grown in soils treated with lead arsenate and calcium arsenate not available since the plants failed to develop.

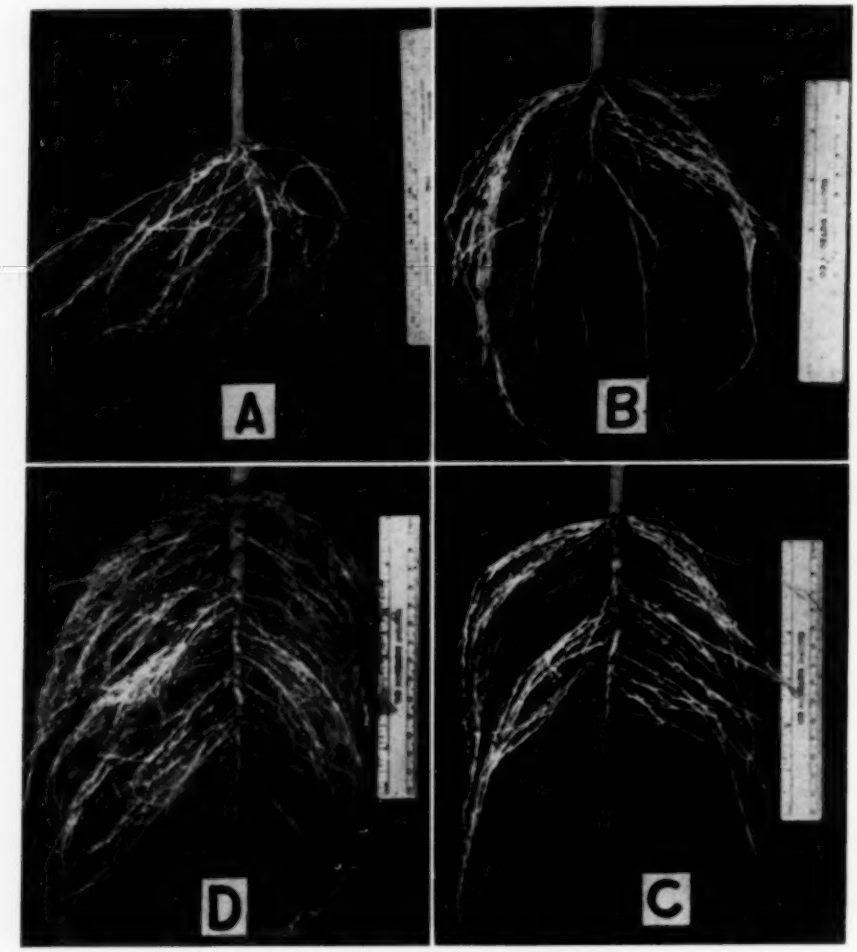

FIG. 3.—Roots of Peppers in Clay Loam

A. 1500 lbs. per foot acre of lead arsenate
B. 1500 lbs. per foot acre of calcium arsenate
C. 1500 lbs. per foot acre of natural cryolite
D. Control

flasks were shaken vigorously from time to time and kept at room temperature. After 10 days the samples were filtered and analyses of the filtrates were made to determine the arsenic trioxide or the fluorine content. Soluble fluorine was determined by distilling an aliquot of the filtrate and analyzing for fluorine by the peroxidized titanium method (Food and Drug Administration 1937). The water soluble arsenic trioxide was determined by analyzing the filtrate using the Gutzeit method.

The total arsenic trioxide was determined by digesting a two gram sample of soil with sulfuric and nitric acids followed by an analysis by the bromate method for soils according to the Journal of the Association of Official Agricultural Chemists (1940). The total fluorine in the soil was found by igniting at 600° C. a mixture of 2 grams of the soil and 1 gram of fluorine-free lime. After cooling, a double distillation with sulfuric acid was made. The temperature of the first distillation was 165° ± 5° C. and that of the second distillation 133° ± 3° C. An aliquot of the second distillation was taken for the determination of fluorine by the peroxidized titanium method facilitated by the use of the wedge photometer (Food and Drug Administration 1937).

DISCUSSION.—The maximum growth of the plants as recorded in tables 1 to 4 inclusive reveals that natural cryolite, even in high concentrations in the soil, caused no appreciable visible injury to plants in clay soil and only slight injury to plants

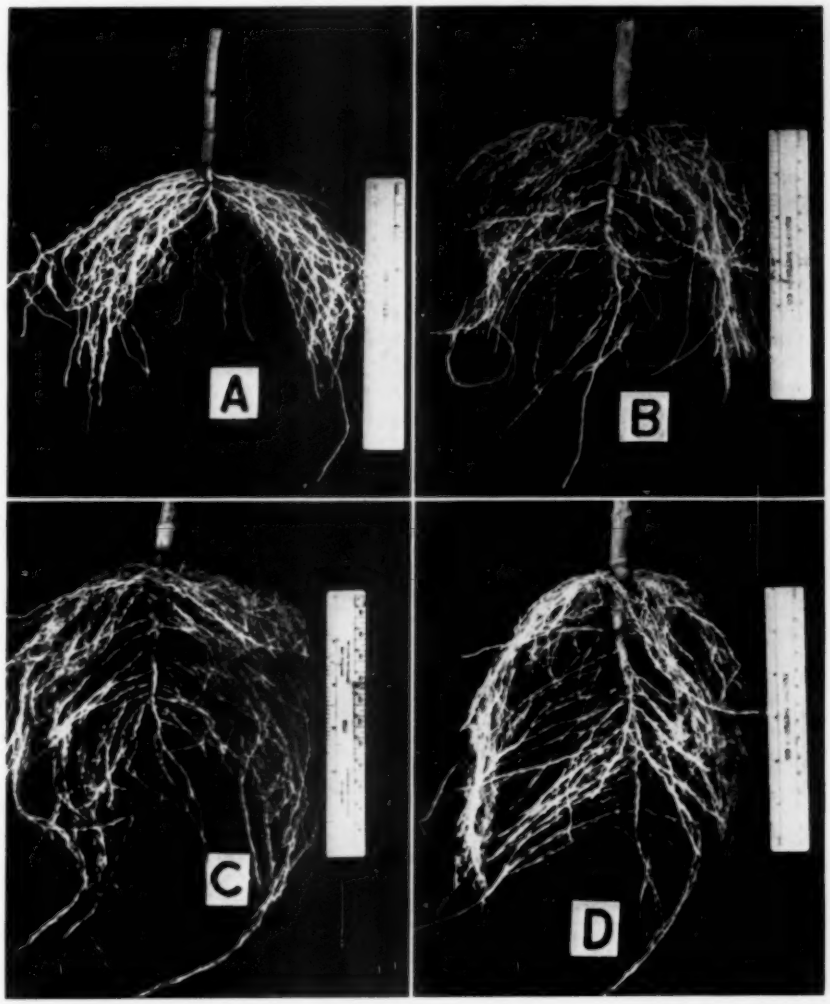

FIG. 4.—Roots of Peppers in Sandy Loam.

A. 1500 lbs. per foot acre of lead arsenate
B. 1500 lbs. per foot acre of calcium arsenate
C. 1500 lbs. per foot acre of natural cryolite
D. Control

in sandy soil. This is in contrast with the very toxic effects of lead arsenate and calcium arsenate in similar concentrations and soil conditions. Lima beans in particular, would not even germinate in any of the arsenic-treated soils except in the 500 pounds per foot-acre clay loam series.

The fruit of the bean and pepper plants was picked when mature and weighed while fresh. The mean yields for the season as given in tables 1 to 4 inclusive show that natural cryolite in the soil had little significant effect upon the yields of either beans or peppers, compared with very marked reductions of yields of plants in lead arsenate and calcium arsenate treated soils.

With the exception of the fruit, all plant material above ground, such as leaf and stem drops, was collected during the season in paper sacks for each individual box of plants. At the conclusion of the tests, the remaining leaves and stems were added to their respective sacks for drying. The plant material was dried at 120° C. until a constant weight was reached. The results under the dry weights of plants in the tables are fairly consistent with the growth and yield data.

Root growth is greatly influenced by soil poisons. For this reason detailed inspections were made of root development at the conclusion of the season. The extent of root development was found to be

closely correlated with the plant growth and yield above ground. Examples of some of the root formations are shown in figures 1 to 4, and their relation to the growth and yield data in the tables is apparent.

The results of the soil analyses (tables 1 to 4), indicate that the soluble fluorine from natural cryolite was apparently converted to less soluble forms during the experiment, especially in clay soil. The percentage of soluble arsenic, generally speaking, was not appreciably reduced over the same period of time.

CONCLUSIONS.—In this investigation, natural cryolite in the soil had little or no effect upon the growth of lima beans and bell peppers.

MacIntire *et al.* (1935) stated in regard to soils, "The ultimate fate of added fluorine—formation of calcium fluoride—would be the same for additions of sodium silicofluoride, cryolite, and other fluorine compounds. It is therefore apparent that no deleterious effect is to be expected from the amounts of fluorine that are used as sprays or dusts, and that no cumulative effect could result from their continued use." The Arkansas Experiment Station (1934) made a similar observation. The soil analyses made at the conclusion of the present investigation apparently are in accordance with the foregoing predictions.

SUMMARY.—Observations were made on high concentrations of lead arsenate, natural cryolite, and calcium arsenate in sandy loam and clay loam soils, and their effect upon the growth and yield of bush lima beans and bell peppers grown in treated soils.

Lead arsenate and calcium arsenate at all concentrations employed in the soil resulted in a considerable reduction of the plant growth, yields, and root development. Natural cryolite in the soil, however, had little effect upon the plants, other than slight reductions in the length of the tap root in the 3000 lbs. per foot acre concentrations in sandy loam.

Soluble fluorine in the soil, derived from the addition of natural cryolite, was noticeably reduced after the experiment as revealed by the soil analyses at the beginning and at the end of the experiment. Determinations of the soluble arsenic in the soils support previous reports by other investigators that arsenic remains in the soluble toxic form in certain types of soil for a number of years.—9-16-42.

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Waste Celery as a Breeding Medium for the Stablefly or "Dog Fly," with Suggestions for Control

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A severe localized outbreak of the stablefly, or "dog fly," *Stomoxys calcitrans* (L.), was reported at Sarasota, Fla., in May 1941.[1] A study revealed that dense breeding of the pest occurred in huge quantities of waste celery strippings. Observations made at different celery processing plants suggested that the condition was of rather general occurrence, especially in locations where a new method of washing and chilling celery has been in use during the last few years.

reductions of approximately 25 per cent in the milk flow. According to reports, the localized outbreaks extended 8 to 12 miles from the celery plants.

The present paper reports the discovery that waste celery is another important breeding place of dog flies in Florida. Two other important kinds of breeding media reported by the writers include shore deposits of marine grasses on bays and inlets and peanut litter left in the fields of northwestern Florida (Simmons & Dove 1941).

Fig. 1.—Waste celery. That on the left of the road is a recent deposit of green strippings, whereas that on the right is about 3 weeks old and has shrunken to a few inches in depth. Sarasota, Fla., 1941.

During April, May, and part of June both dog flies and houseflies were very abundant in the areas where celery is grown. Workers in the fields and about the washing plants reported that they were badly annoyed by the bites of the dog fly, and the residents also complained of this pest. In the vicinity of washing plants cattle suffered severely, and some of the owners of dairy animals reported

Present Methods of Handling Celery Strippings.—When celery is cut, only a portion of the undesirable stalks are stripped in the fields, and as a result the amount of litter left in the fields is of minor importance. After the celery is trucked to the processing plant and is washed, all diseased, broken, or dried stems, and all undersized bunches are discarded. This litter is trucked to some convenient place and is dumped in piles, which range from 1½ to 2¼ cubic yards each (Fig. 1). Later the piles may be leveled with a harrow and plowed under in the sandy soil. Usually a washing plant

[1] Severe annoyance from dog flies around celery packing plants was investigated by F. C. Bishopp in the vicinity of Sarasota, Fla., in April 1939. The source of the trouble was found by him to be celery trimmings dumped on nearby fields. He recommended scattering of the waste material on open areas in the woods, where the material would dry rapidly. The writers were not aware of this finding until after the work reported herein was initiated.

dumps its strippings on the same small plot of land, consisting of 1 to 3 or 4 acres, from December until May, and at irregular intervals the plowing-under procedure is repeated. Plowing usually occurs after the litter is heavily infested with larvae and pupae, in which case development continues in the soil, and the field becomes a veritable "fly factory." Even where uninfested strippings are plowed under, the coverage is seldom sufficient to prevent heavy infestations. Some washing plants dump their strippings on waste land, where the accumulations may attain a depth of 5 feet, and make no attempt to plow them under the soil (Fig. 2). These strippings shrink to about one-ninth of their original volume in approximately 2 weeks, and, when they lose most of their water, fermentation results in heavy infestations. Other celery processing plants handle the waste strippings in about the same manner as at Sarasota.

FIG. 2.—Waste celery piled 5 feet deep in woods, no attempt having been made to plow it under. Manatee, Fla., 1941.

EXTENT AND LOCATION OF CELERY GROWING IN FLORIDA.—The locations and unofficial acreages of the five principal celery-growing areas in Florida are Sanford 5000, Belle Glade 1500, Sarasota 1350, Wiersdale 400, and Island Grove 100, or a total of 8350 acres.

The total number of processing plants in Florida is not known, but in the Sarasota area there are 6 plants, or 1 for each 225 acres of celery. On this basis there may be as many as 37 plants in the State. The number may be greater, since owners of washing establishments are of the opinion that 100 acres of celery will justify the erection of a processing plant.

As much as 50 truck loads (75 to 112 cubic yards) of strippings are hauled away from some of the plants each day, and it seems conservative to estimate that the average is about 25 to 30 loads per plant per day. This would make a total of more than 1000 loads per day in the state. Celery processing begins in most of the areas about December 15 and continues until May, or later, each year, or for a period of about 5 months annually. On this basis it is believed that approximately 120,000 loads of waste strippings are exposed to flies during the winter and spring months of each year in Florida.

DOG FLY BREEDING IN STRIPPINGS IN THE FIELDS.—When celery is cut in the field, only the very poor stalks and greatly undersized bunches are discarded by the workers. This waste is sufficient to form a thin layer of green litter over the field. A

few eggs were found on these strippings, and in low, damp places and occasionally in small piles a few immature larvae were found. In the dry weather that prevailed during this investigation the strippings lost their water and soon became so dry that the larvae failed to reach maturity. In a harvested field only one pupa was found during the entire investigation.

It is the usual practice to plow celery fields within a few days after harvesting and to plant a summer cover crop. Plowing is deep and the strippings are very thin, so that this procedure alone would preclude most, or all, of the fly breeding in these fields.

If strippings were left exposed during wet weather, they might, in certain places, constitute a potential breeding place for flies, but such a condition has not been encountered, and, in general, the field strippings are not considered important breeding places for flies.

EMERGENCE FROM PLOWED-UNDER CELERY STRIPPINGS.—In tests that were conducted on the plowing-under of strippings of various ages, it was found that complete coverage of the long rigid stalks was difficult and that the portions left exposed to the flies readily became infested and produced dog flies. It was almost impossible to plow under strippings before they became infested with eggs, and, when thick layers of them were turned under, the bulk of material and the high moisture content probably permitted the larvae to complete their development.

In order to determine the value of the practice of plowing under celery strippings, cages were erected in fields where the strippings had been plowed under throughout the celery-harvesting season. One cage covering 36 square feet of plowed ground captured 11,700 flies in 5 days, of which approximately 11,653 or 99.6 per cent, were dog flies. In a period of 24 hours, 6000 dog flies were caught, 3500 of them emerging within 4 hours. The calculated emergence of dog flies during a single day was between 2 and 3 million flies per acre.

The observations demonstrate that the present system of plowing or disking under of celery strippings is not effective in control of dog flies. Also, previous experiments by the writers have shown that dog flies will emerge with ease through 4 to 6 inches of loose or sandy soil and that one-third of the normal number will emerge from a depth of 8 inches (Simmons & Dove 1941). It is evident, therefore, that, after litter infested with prepupae or pupae is plowed under, it will continue to produce flies.

BREEDING OF DOG FLIES AND HOUSEFLIES IN PILES OF STRIPPINGS.—From celery strippings 2 to 3 weeks old, which had shrunken to a depth of about 3 inches, 20 ounces (85 cubic inches) of the material, which was almost dry, was collected on May 12 and caged until May 26. During this time 2679 dog flies, or 54,462 flies for a cubic foot of the material were produced. Two quarts of the dried strippings taken on May 12 produced 21,001 adult houseflies in 11 days, or 315,015 flies per cubic foot of medium. The flies were measured with a 100-cc. graduate, and the number of measures was multiplied by the average number of flies contained in such a graduate. In selected places the maximum breeding density of houseflies exceeded that of dog flies, although this was not uniformly true (Table 1).

A summary of fly emergence in 7 cages placed over 148.2 square feet of infested litter is shown in table 1. In the larger cages the total number was ascertained by counting the flies on representative sections of the screen and by calculating the number for the entire cage. The percentages of dog flies and houseflies were determined from samples of 100 flies obtained at random throughout the cage. The numbers and percentages of the two kinds of flies in the smaller cages were determined by identifying and counting each insect. A heavier emergence occurred in the smaller cages because they were placed over selected, densely infested litter.

In one cage set over litter 3 inches deep as many as 644 dog flies emerged per square foot during a 15-day period. In another cage a square foot of material produced 219 houseflies and 258 dog flies in an 11-day period.

RATE OF DEVELOPMENT IN SHRUNKEN PILES OF STRIPPINGS.—To ascertain the rate of development of dog flies, green celery strippings were exposed in piles in the open and were examined at frequent intervals. Some of the strippings became infested with eggs within a few hours after they were dumped. The first instars were difficult to find but within 2 to 3 days subsequent to egg laying the larger larvae

were found without difficulty. In several instances second instars were present as early as the fourth day after the litter was dumped. In six piles of litter approximately full-size third instars were present after 7 to 14 days, the average period being 9 days. After 11 to 15 days of exposure pupae were present. With the usual pupal period of 7 days, the developmental period under these conditions from egg to adult would be 18 days.

produce more than one generation of flies also appears to depend upon the size of the pile and upon the weather conditions. Strippings that were piled only about a foot thick desiccated so fast during dry weather that they did not permit development of a second generation of dog flies. Old strippings often contained many third-stage larvae and pupae, but were not infested with younger stages, because the material was no longer suitable for fer-

Table 1.—Fly emergence in cages placed over shrunken piles of infested celery strippings at Sarasota, Fla., in the spring of 1941.

Cage No.	Days Cage Was in Operation	Surface Area Covered, Square Feet	Total Number of Flies	Number per Square Foot	*Stomoxys calcitrans*		*Musca domestica*	
					Number per Square Foot	Per Cent of Total	Number per Square Foot	Per Cent of Total
1	15	1.4	1,047	748	644	86.1	103	13.9
2	15	1.4	1,032	737	601	81.6	136	18.4
3	11	1.4	667	476	258	54.1	219	45.9
4	15	36.0	8,932	248	236	95.0	12	5.0
5	15	36.0	4,675	130	110	84.5	20	15.5
6	14	36.0	5,478	152	148	97.5	4	2.5
7	11	36.0	5,015	139	98	70.4	41	29.6
Total		148.2	26,846					
Average for cages 1 to 3				654	501	76.7	153	23.3
Average for cages 4 to 7				167	148	88.4	19	11.6

Infestations in celery strippings apparently depend more upon the size of the pile and the depth of the litter than upon its age, and the periods given above should not be considered as the minimum for different conditions. When celery was piled to a depth of 4 or 5 feet, it was relatively slow in producing adult dog flies, and in some instances it did not become heavily infested even after an exposure of 2 weeks. The large quantity of water present during the initial stage of decay seemed to render the litter too wet for favorable dog fly breeding. After the litter had lost much of its water and had shrunken to a few inches in depth, the infestations were found to be heavy. The interval between the dumping of the litter and the emergence of flies may therefore be several weeks in some instances and a relatively short time in others, depending upon the suitability of the strippings for breeding media.

The ability of uncovered strippings to

mentation. Houseflies seemed to reinfest old, badly decayed strippings much more readily than did dog flies. Where strippings of different ages were repeatedly piled in one place, continuous breeding of both dog flies and houseflies was the rule. In addition to these, dense breeding of *Drosophila repleta* Woll. and the soldier fly, *Hermetia illucens* L., was encountered.

If strippings are piled 6 inches deep or less and are subjected to hot, dry weather, they may become infested, but owing to rapid drying the larvae either die or pupate prematurely.

LARVICIDE TESTS.—Thirty-six tests employing 12 materials were conducted for the destruction of dog fly larvae in celery strippings. With a few exceptions, all the liquid insecticides were applied with a power sprayer, operating at 250 pounds' pressure, on plots averaging 273 square feet in size. This amount of material was equivalent to approximately 3740 cubic feet of strippings.

Gas condensate and creosote seemed to show more promise than other materials tried. When they were used in the proper strength and quantity, they killed the larvae and prevented reinfestations. Gas condensate, a byproduct from the manufacture of commercial gas consisting of a light caustic fraction, was mixed in approximately equal proportions with a heavy tarlike fraction. This mixture had the color and consistency of ordinary creosote oil and sold for about 7 cents per gallon at most plants. It contained tar, ammonia, a residue of heavy oil, sulfur, benzene, toluene, creosote, anthracene, and other coal-tar fractions, and was found to be very toxic to dog fly larvae. When 55 gallons of a 10 per cent aqueous mixture of the coal-tar gas condensate was applied to a plot of strippings 5 inches deep on an area of 144 square feet, a complete kill of the larvae resulted. There were three truck loads of strippings, which had been exposed for 16 days. The dry, uninfested top portion was removed to facilitate spraying and to conserve the insecticide. The cost of material was about 13 cents per load with the methods employed. Pupae collected 3 days after treatment showed a survival of only 19.1 per cent, but in one or two lightly treated areas a reinfestation of houseflies occurred.

Undiluted gas condensate prevented reinfestations and gave a longer period of protection than the 10-per cent mixture, which is considered an important factor in the treatment of green strippings. If No. 2 fuel oil is mixed with the condensate, it serves as a good spreader. One part of creosote mixed with 3 parts of fuel oil is an effective and readily available larvicide. The quantity required is approximately the same as that for gas condensate.

Powdered commercial cyanamid was also an effective larvicide in the one test made. After the uninfested top was removed, 8 pounds of cyanamid was sprinkled heavily on 54 square feet of infested strippings, which were 6 inches deep. The plot was then thoroughly wet with 30 gallons of water. From it the pupal emergence was only 2 per cent, but a reinfestation of houseflies occurred in the old material. The cost of insecticide for treating the infested portion of one load of strippings was 18 cents. On land that is to be cultivated there may be times when the use of cyanamid would be advisable.

Lead arsenate, calcium arsenate, pyrethrum, and dichloroethyl ether were very effective as larvicides, but they permitted reinfestations of houseflies, failed to kill the pupae, or were too expensive for general use.

If celery strippings become infested, they may be treated effectively with either gas condensate or creosote, as recommended above. Such treatments should be considered as emergency measures, because, as is subsequently shown, it is more feasible to treat the litter to prevent infestations.

Where fields of infested strippings have been plowed under, any treatment to prevent fly emergence is very expensive. This may be accomplished, however, by sprinkling the surface with a 10-per cent emulsion of ethylene dichloride in water at the rate of about 1500 gallons per acre. The cost of material alone for such a treatment is about $25 per acre.

TREATMENT OF GREEN STRIPPINGS TO PREVENT FLY BREEDING.—The most feasible way of handling the fly-breeding problem seem to be the treatment of celery strippings before they become infested. Twenty tests were made on the prevention of dog fly breeding in green celery. Of the materials tried, creosote, gas condensate, and paris green were effective, and borax showed some promise in one test.

A 10-per cent aqueous mixture of creosote applied with a power sprayer at the rate of 16 gallons per load (about 2 cubic yards) of strippings was effective in preventing fly breeding. The cost of the material was 50 cents. A 25-per cent solution of creosote in No. 2 fuel oil applied at the rate of 8 gallons per load also prevented breeding and insured protection for a longer period. Except for rainy weather or in very deep strippings, it is doubtful whether the additional protection obtained from this mixture would justify the increased cost.

Undiluted gas condensate mixed with the heavy fractions of the same material prevented breeding when applied at the rate of 10.5 gallons per load of strippings. The local cost of this material was about 65 to 70 cents. Like creosote, the gas condensate is not soluble in water and therefore will remain on the litter during rainy weather. Different uses made of the gas

condensate show that it can be diluted with No. 2 fuel oil or mechanically mixed as a water emulsion at a reduced cost. In order to insure good penetration and thorough coverage, all treatments should be made with a power sprayer.

Paris green, when used with a power sprayer at the rate of 1.5 pounds with 8 pounds of hydrated lime in 45 gallons of water to a load of green celery strippings, prevented the breeding of dog flies and houseflies. The cost of materials for this treatment was 68 cents. Since these tests were made during dry weather, the effectiveness of a water-soluble insecticide during wet weather was not ascertained.

Some tests on scattering to prevent breeding of flies were conducted with green celery, and observations were made on strippings that had formerly been placed in piles of different depths. It was found that strippings scattered to a depth of 3 or 4 inches during dry weather dried rapidly and did not permit any breeding. Because it is not known just how thin the strippings would have to be spread in order to prevent breeding during rainy weather, scattering could not be recommended as a means of control. The probability of rain would preclude the recommendation of a treatment that was good only during a dry season. Moreover, the large quantity of material would necessitate a large tract of land that would be suitable for scattering, a facility that would not be available in the vicinity of most plants.

From the test made it is obvious that green celery may be treated to prevent fly breeding. The cost of such treatments on uncrushed material would limit the use of the method, but it is practicable to crush and reduce the volume of the strippings so that the quantity of celery requiring treatment would be relatively small.

TREATMENT OF CRUSHED STRIPPINGS TO PREVENT BREEDING.—According to estimates made by celery-processing establishments, it costs from 50 to 60 cents per load to dispose of the celery strippings. In an average-size washing plant this amounts to about $25 per day. If the strippings were treated as they are conveyed from the washer, it would cost about $25 additional for materials.

In the spring of 1941 a commercial celery-juicing plant at Sanford utilized a thousand tons of waste strippings during a period of 5 weeks. In the process of obtaining juice the bulk of the strippings was reduced to approximately 25 per cent of the original size. The strippings were run through a hammer mill and then through a roller press so that about 90 per cent of the juice was extracted. When some of the pulp from the press was examined where it had been dumped and exposed, it was found to be heavily infested with both dog fly and housefly larvae and pupae. The plant operators estimate that a roller press without the use of the hammer mill would have reduced the bulk of the material to about 35 per cent of the original volume. Such apparatus can be installed at the end of the conveyor chain so that the strippings can feed into it automatically. In practice, a plant producing 50 loads of strippings per day could, by crushing, reduce the volume to about 17 loads, or 33 loads less than normal. The elimination of handling costs for these 33 loads, at 50 cents a load, would result in a saving of $16.50 per day. This saving would permit an expenditure of 97 cents per load for treating the remaining 17 loads of crushed strippings. Since cost of the material for treating a load would not exceed 65 cents, there would be a net saving of 32 cents per load, or a daily saving of $5.44. Since most plants operate 5 months a year, there would be an annual saving of approximately $652, more than enough to absorb the cost of the crusher. If the crushed celery were conveyed automatically through a vat containing gas condensate or creosote,[2] just as it is now conveyed through vats of water at a juicing plant, no additional labor would be required. Even if more chemicals were used than the amounts found necessary for crushed strippings, the savings in the cost of labor for handling the smaller volume would probably compensate for the additional expense. If crushed strippings absorbed more than the usual amount of material, it would be possible to remove the excess by passing the material automatically through an auxiliary roller unit. If both the hammer mill and the roller press were used, the bulk of the strippings would be reduced even more, so that additional saving would result from further decreases in the bulk of the material. Moreover, the sales

[2] It has recently been found that an aqueous solution of sodium arsenite is just as effective as, and more economical than, either creosote or gas condensate.

resulting from a larger volume of juice would no doubt absorb the cost of the hammer mill.

Because the amount of land necessary to receive the smaller quantities of crushed strippings would be only about one-third as much as that for uncrushed celery strippings, the cost of constructing a fence about the dumping area would be less and cattle on the free range could be kept away.

SUMMARY.—Waste celery is reported as an important breeding place for dog flies in Florida. At Sanford, Belle Glade, Sarasota, Wiersdale, and Island Grove the present methods of disposing of about 180,000 to 270,000 cubic yards of waste celery have resulted in severe localized outbreaks.

The maximum density of dog fly breeding was calculated at 54,462 flies per cubic foot and in selected places the housefly breeding was even more dense. Soon after exposure green strippings became infested and in a little less than 18 days they produced adult dog flies.

Where infested strippings were plowed under, third-stage larvae and pupae continued to produce flies. One cage containing 36 square feet of plowed-under strippings produced a total of 11,653 dog flies within 5 days.

For the treatment of infested litter some effective insecticides were found, but on account of the expense and time involved in treating the huge quantities it is suggested that the waste be crushed at the washing plants and that the pulp be conveyed automatically through a vat of diluted creosote or gas condensate. It appears that the saving from treating the smaller quantity of waste would more than offset the cost of the crushing machinery and insecticide.—2-26-42.

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Three Curculionid Pests of the Oiticica Nut

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Recently the nuts of the oiticica tree, *Licania rigida*, Benth., have become of commercial importance as a source of a fairly light colored oil which greatly resembles tung oil in odor and in many of its other physical and chemical properties (Gardner 1934).

The oiticica trees, which produce a dense evergreen foliage, grow wild in great abundance in some of the river valleys of northeastern Brazil. They grow for 100 years or longer and may reach a height of 90 feet or more. The trees are capable of withstanding long droughts, flower in August and September, and bear a nut-like fruit which is harvested from December to March. Fully ripened fruit falls to the ground, but the natives obtain much by shaking the trees. This fruit, rather ovoid in appearance and one to one and one-half inches in length (Fig. 1), consists of a brick colored seed with a thin shell which in turn is covered with a soft layer of green fruity tissue about 3 mm. thick. The dry seed contains about 60 per cent by weight of the oil. The fruits are generally dried or cured in the sun before being put in the presses.

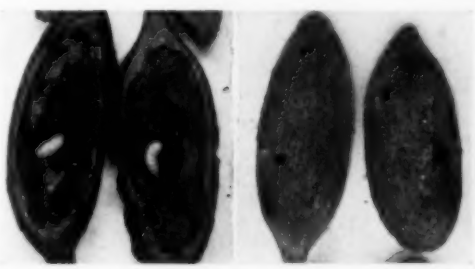

FIG. 1.—Dried oiticica nuts showing larvae and pre-emergence holes.

Serious insect damage to the oiticica nut crop was brought to the attention of the writer by a Brazilian company producing this oil (Pyenson, 1938b). Sample nuts brought to the laboratory contained curculio-type larvae which fed on the contents of the nuts and greatly reduced their oil content. In addition it was re-

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ported that there was much premature dropping of the nuts due to the attacks of these pests.

In order to make some further investigations and collect more infested nuts, a trip was made into the interior of Parahyba at the end of the harvesting period. The investigations were made in a grove of about 100 trees since the large oiticica forest could not be reached because of a flooded river. About 75 per cent of the nuts in this location when cracked open were found to be infested with the curculio larvae (Fig. 1). Some nuts that had been on the ground for some time had emergence holes in them (Fig. 1). By digging in the soil around the nuts several larvae and pupae were found 1 to 1½ inches below the soil surface. The presence of pupae indicated the presence of adults, but none were found.

FIG. 2.—Three pests of the oiticica nut (greatly enlarged), A—*Conotrachelus licaniae*, Marshall, B—*Conotrachelus* sp. (new?), C—*Conotrachelus* sp.

DESCRIPTION AND HABITS OF ADULTS.—Adults (Fig. 2A) reared from infested nuts by placing them in damp soil were identified as a new species, *Conotrachelus licaniae*, by Marshall (1937). *C. licaniae* was the dominant species reared from the nuts. Two other species of the genus (Fig. 2B and C) were reared from the nuts, but the war has interfered with their identification by Sir Guy Marshall of the British Museum, who states that they are probably new. These two species were reared in lesser numbers; however, batches of nuts from other localities might show one of these two species dominant.

The three different species of *Conotrachelus* reared from the infested nuts appear to have parallel life cycles and larval habits according to the laboratory observations, but differ in the reactions and appearance of the adults.

Conotrachelus licaniae (Fig. 2A) is thickly speckled on the dorsal surface with white and brown scales. The sides of the prothorax and the whole ventral surface is covered with white scales, while the top of the head is mostly covered with the brown scales. The insect averages about 6 mm. in length, is very active during the day, flies readily but drops and feigns death when disturbed.

The second *Conotrachelus* species reared (Fig. 2B) is slightly larger and longer than *C. licaniae* (averaging about 7.5 mm. in length) with a shorter stouter beak, which generally remains protruding forward when at rest or disturbed. The insect is thickly covered with light tan scales, except for the basal half of the elytra where reddish-brown scales predominate. These cuculios usually remain quiet during the day, resting in sheltered spots.

The third *Conotrachelus* species (Fig. 2C) averages about the same size as the second but is wholly brown in color with sparse small whitish narrow scales covering the body. The elytra are heavily ridged and the beak is always held forward even when the insect is disturbed. This species also tends to remain quiescent during day. Normally all three species feed on the outer fleshy part of the oiticica nut and evidently deposit their eggs in it, but in the laboratory they also fed actively on the fleshy part of the tree "oiti

da praia" which is closely related to the oiticica.

LABORATORY OBSERVATIONS —The infested seeds that were collected in Parahyba in January and February were subjected to various environmental conditions to attempt to determine the seasonal history of the insects as affected by climate. The temperature in the laboratory during these observations averaged about 80° F.

Mature larvae were taken out of the infested nuts and placed in damp soil. Under these conditions most of them went into the pupal stage in from 10 to 15 days and became adults in from 5 to 7 days longer. The adults remained some time in the soil before emerging, making the total time spent in the soil as larvae, pupae, and adults from 20 to 30 days. Larvae placed in dry soil at the same time failed to enter the pupal stage and all eventually died from desiccation.

Nuts with pre-emergence holes (Fig. 1) were placed in dry soil and damp soil. An examination one month later showed that all larvae had emerged from the nuts in the damp soil while none had emerged in the dry soil. When the nuts in dry soil were transferred to damp soil larvae began to emerge from them within a week. The same results were obtained when infested seeds without holes were placed on damp and on dry soil. No emergence holes appeared in the nuts in the dry environment while holes began to appear in a few days in the damp environment. If the external environment becomes dry after the emergence holes are made the larvae remain in the nuts until conditions become favorable. Damp conditions are evidently favorable for the continuous and rapid development of the curculios.

For some unknown reason not all the larvae emerged from nuts placed over damp soil, even after a period of three months or more. Also some larvae underwent a diapause in damp soil for as long as 3 months or more.

A batch of 17 nuts, kept in a dry place for 6 months, were examined and found to contain nine living larvae—six *Conotrachelus licaniae*, and three of the brown and tan species. Another batch of 17 nuts kept under the same conditions for 7 months and 20 days contained five living larvae. *C. licaniae* adults emerged from the soil 19 days after the larvae were placed in it. Evidently the larvae can continue feeding in the nuts for long periods until favorable conditions develop.

Adults fed on fruit for the first 15 days after emergence stayed alive for 2 months afterwards with only a little water supplied occasionally. This points to adult longevity. Neither adults nor pupae were observed to undergo a diapause in any environment.

DISCUSSION —Since the oiticica is a tree indigenous to the regions where it is found at present, the curculios must have been pests of the nuts for years, but remained unobserved because only recently has the value of the nuts been realized. The abundance and destructiveness of these pests appear to be governed mainly by seasonal weather conditions, as no parasites were reared from any of the infested nuts. In the interior of Brazil the rainy season usually begins late in February and ends in June. During the rest of the year the weather is generally very dry with infrequent rains (Pyenson 1938a).

The absence of fruit from the oiticica trees from March to September indicates either a long diapause during some stage of the life of the curculios, the presence of another host or hosts, or adult longevity. The observations made indicate that the curculios may survive through the ability of the larvae to remain in the nuts for as long as 7 months or more, or to undergo a diapause in the ground for 3 months or more. Also the laboratory observations indicated that adults are long-lived and may carry through the fruitless part of the season by feeding on the foliage of the oiticicas, or by turning to other host plants. Since it is reported that the attacks of these curculios produce dropping of immature stages of the fruits, it appears that adults are present during the dry months. It is possible that all the above observed methods of survival are utilized in bridging over the fruitless period of the oiticicas. Several generations of curculios seem possible, depending on the amount of rainy weather as larvae will not leave the nuts if the soil is dry.

CONTROL RECOMMENDATIONS —Until more is learned about these curculios only simple and inexpensive control measures should be practiced. The control of these pests presents difficult problems, since the oiticicas are huge trees growing wild along river beds that may be dry in the dry sea-

son and flooded during the rainy season.

Ripened nuts should be picked frequently, about twice a week, and care should be taken to leave no nuts lying around after picking. No trees should be left in the vicinity with unpicked nuts on the ground. Clean picking maybe facilitated by clearing away all growth under the trees. The oil should be extracted from the nuts as soon as possible after picking as the larvae continue feeding and cause much valuable oil to be lost. Nuts dropping prematurely should be raked up frequently and destroyed.—4-30-42.

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Certain Plume Moths of Economic Importance in California

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California has five species of plume moths (family Pterophoridae) in the genus *Platyptilia*, which cause damage of economic importance either to agriculturally grown plants or, in one case, to plants of importance as sources of nectar for honeybees. The species involved, listed in order of their importance, are presented as follows: the artichoke plume moth, *Platyptilia carduidactyla* (Riley), the snapdragon plume moth, *P. antirrhina* Lange, the calendula plume moth, *P. williamsii* Grinnell, the sage plume moth, *P. fuscicornis* Zeller, and certain races of *P. pica* (Walsingham) which occasionally select cultivated snapdragon and geranium (*Pelargonium* spp.).

The purpose of this paper is to bring together all of the available information concerning this group of insects and to present keys to the adults and larvae so that the species can be readily separated. The more technical features of the immature stages and the systematics of the group have been prepared in a separate paper by the writer and will not be presented here. Where the biology and control of a species has already been published only a brief mention of this available information will be given. Control measures have been developed only for the artichoke plume moth and the snapdragon plume moth.

KEY TO ADULTS.—Inasmuch as the identification of the adults through a knowledge of the larval food plants is not entirely satisfactory due to the overlapping in the selection of plants, it was thought advisable to present the following illustrated key to assist in their separation. The adults are shown in figure 1.

Key to species of *Platyptilia* of California

1. Scale tuft on inner margin of third feather of secondaries located at two-thirds the distance from base of feather; larvae feed chiefly on sages (*Salvia* spp.) ..... *fuscicornis* Zeller
   Scale tuft at end, just before center, or just beyond center of feather 2
2. Scale tuft on inner margin of secondaries located at end of feather; larvae feed on cultivated snapdragon (*Antirrhinum* spp.) ..... *antirrhina* Lange
   Scale tuft arising from just before center of just beyond center of feather 3
3. Scale tuft on inner margin of secondaries arising from just before center; apices of primaries not noticeably produced 4
   Scale tuft arising from just beyond center; apices of primaries produced; the larvae feed chiefly on various members of the plant family Scrophulariaceae ..... *pica* (Walsingham)[1]
4. Scale tuft on inner margin of secondaries distinctly triangular; color of primaries buff-brown; larvae feed chiefly on *Cirsium* and *Cynara* (Compositae) ..... *carduidactyla* (Riley)
   Scale tuft reduced, not distinctly triangular; color of primaries grayish-brown to gray, with black markings; larvae are general feeders on Compositae ..... *williamsii* Grinnell

In instances where the visible patterns of the wings are destroyed, as is often the case with material collected at light traps,

[1] The form figured, (Fig. 1-3), is *pica cratacea* Fletcher, found in the central coastal region of California.

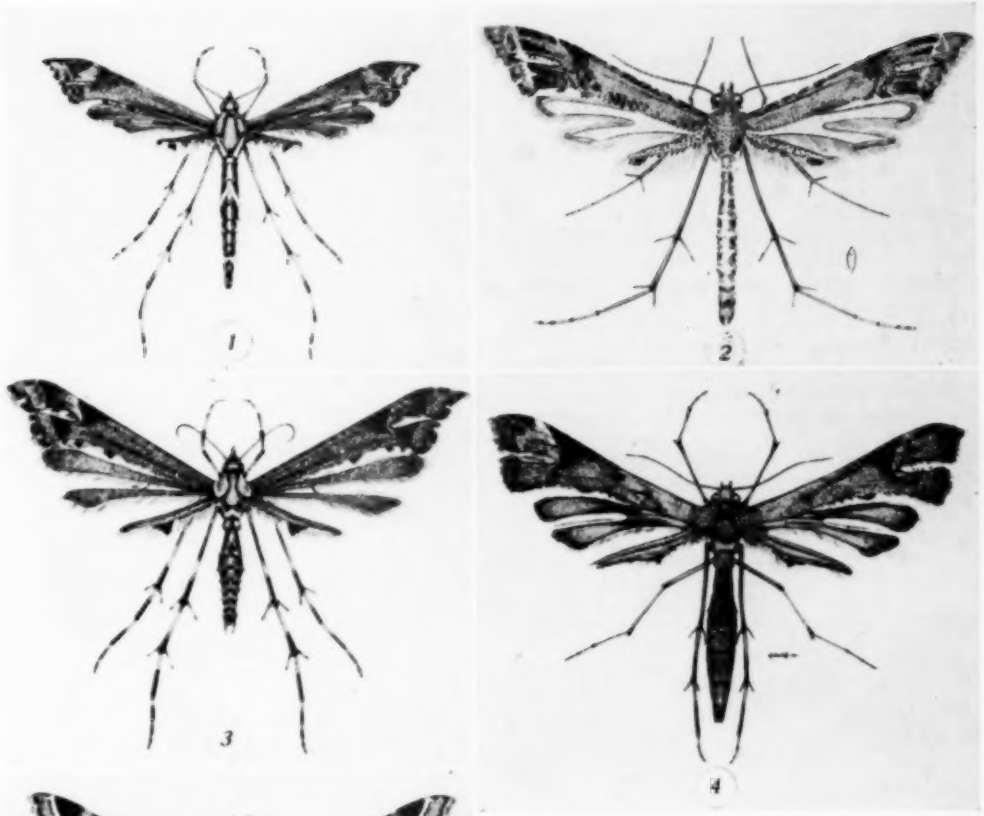

FIG. 1.—California species of *Platyptilia;* 1. *fuscicornis* Zeller; 2. *antirrhina* Lange; 3. *pica crataea* Fletcher; 4. *carduidactyla* (Riley); 5. *williamsii* Grinnell.

the male and female genitalia are useful in giving accurate determinations. The features of the male genitalia are shown in figure 2 and are tabulated in the key below.

1. Harpes (claspers) simple, blade-like, lacking apical processes.....2
   Harpes with apical processes.....4
2. Uncus simple, pointed apically; harpes noticeably divided apically; anellus lobes flap-like.....*fuscicornis* Zeller
   Uncus knobbed apically; harpes not divided apically; anellus lobes slender, finger-like processes.....3
3. Saccus noticeably grooved above; harpes long, slender; aedeagus long.....*carduidactyla* (Riley)
   Saccus only slightly grooved above; harpes one-fifth wider basally; aedeagus about one-fifth smaller.....*williamsii* Grinnell
4. Uncus slender; cucullus of harpe a well-developed apical, hook-like structure; saccus not developed.....*antirrhina* Lange
   Uncus paddle-like; cucullus a small, spine-like structure; saccus developed, armed with projecting spines.....*pica* (Walsingham)

KEY TO THE LARVAE.—The larvae of the species involved can be separated in the key presented below and are portrayed in figure 3. The eggs and pupae of these species also present distinctive features, but these cannot be covered within the scope of this paper.

1. Secondary setae (small setae covering the body, not having definite positions) absent; certain of primary setae with swollen apices; crochets (hooks) of prolegs on abdominal segments 3 to 6

usually 10 in number..... *antirrhina* Lange
Secondary setae present on at least some of the segments; primary setae without swollen apices; crochets of prolegs vary from 7 to 9.....2

2. Secondary setae short, pointed terminally; suranal plate pigmented, at least in part; certain verrucae (warts) pigmented.....3
Secondary setae elongated, usually inflated terminally; suranal plate and verrucae clear, not pigmented.....4

3. Small, mature larva less than 10 mm. long; head light brown with some darker blotches; prothoracic plate with two median, black, longitudinal lines and a black basal spot.. *williamsii* Grinnell
Larger, 15 to 19 mm. long when mature; head and prothoracic plate dark brown to black..... *carduidactyla* (Riley)

4. Prothoracic plate with black markings; prolegs on abdominal segments 3 to 6 with 7 crochets..... *fuscicornis* Zeller
Prothoracic plate lacking black markings; prolegs with 9 crochets..... *pica* (Walsingham)

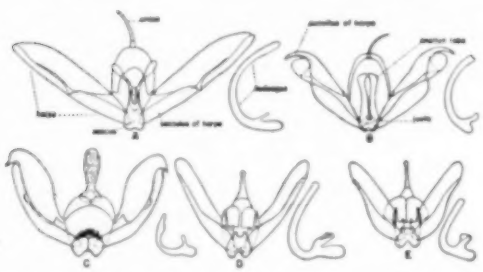

FIG. 2.—The male genital features of *Platyptilia* species; A, *fuscicornis* Zeller, B, *antirrhina* Lange, C, *pica* (Walsingham), D, *carduidactyla* (Riley), and E, *williamsii* Grinnell.

THE ARTICHOKE PLUME MOTH.—The artichoke plume moth is the best known member of the group, being distributed throughout the United States and Canada on various thistles of the genus *Cirsium* and on artichoke and cardoon in certain localities where these plants are grown. The more important features in the biology and control were presented in the article by Lange (1941) and need not be duplicated in any detail here.

Since the presentation of the list of larval food plants in the above mentioned paper, two additional food plants, Canada thistle, *Cirsium arvense* Scop., and *Cirsium americanum* var. *callilepsis* (Greene) Jepson have been found in California. Records obtained through correspondence and the actual receipt of specimens make it possible to add three states to its known distribution, namely, Connecticut, South Carolina and Wyoming.

The economic damage attributed to the artichoke plume moth is chiefly caused by the larval burrowings in the artichoke buds. This injury is shown in figure 4. Losses to artichoke heads during the period 1936 to 1940, during which period records were made, varied from less than 1 per cent to 80 per cent with an average yearly loss of about 10 per cent.

The most economical and effective

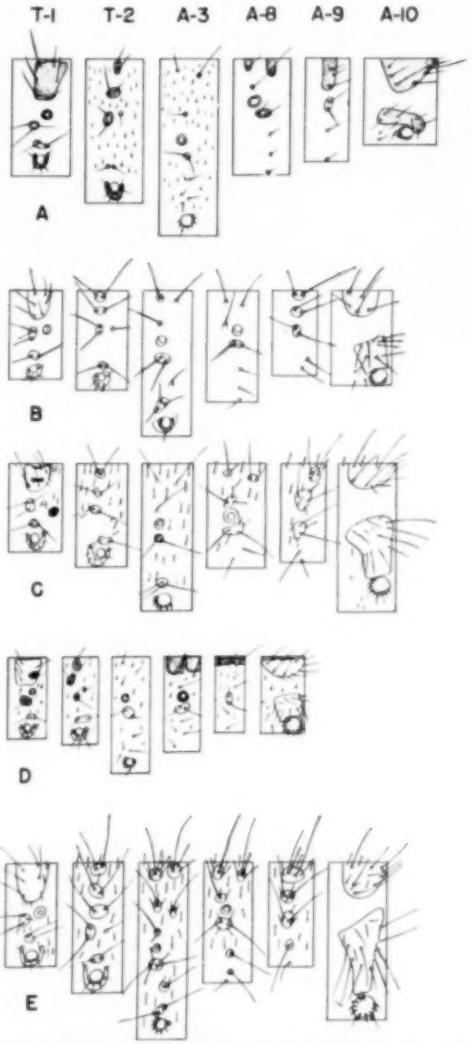

FIG. 3.—Setal formulae of *Platyptilia* species; A, *carduidactyla* (Riley), B, *antirrhina* Lange, C, *fuscicornis* Zeller, D, *williamsii* Grinnell, and E, *pica crataea* Fletcher.

control measures consist of a combination of cultural and field sanitation practices which must be in effect throughout the year. The most important practices include the burying of the plant tops in a

ditch between the rows covered by at least 12 inches of soil (which is done in May and June when the plants are cut), the removal of all wormy artichokes from the field and their subsequent destruction, and the removal of all thistle food plants growing in the environs of artichoke plantings.

THE SNAPDRAGON PLUME MOTH.—Although this insect has been causing damage to cultivated snapdragons in

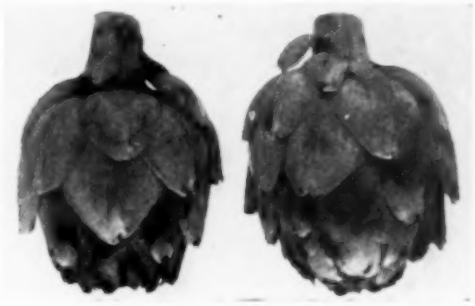

FIG. 4.—Artichoke buds damaged by the feeding of larvae of the artichoke plume moth.

California for a number of years, it has only lately become a serious pest in greenhouses where a specialty is made of snapdragon culture. The absence of any larval parasites would seem to indicate the possibility that this species has been introduced into California. Its rather close relationship to *Platyptilia taprobanes* Felder would indicate a more southern origin for this species. With the movement of snapdragon flowers in commerce it is possible that it may in time be introduced into other localities.

The important features in the life history have been presented in the article by Lange (1939) at the time of its description. Injury to snapdragons is caused by the larval burrowings inside the stems, buds, or green seed pods, minings in the leaves, or external feeding among the terminal leaves or buds and developing flowers. Typical injury to snapdragon plants is shown in figure 5.

The first two larval instars are spent as leaf miners. Later the larvae leave the mines and seek out other parts of the plants. Under outside conditions there is evidence of three overlapping generations a year in central California, although it is quite possible that several more generations a year are possible under greenhouse conditions.

Control experiments conducted during 1941 indicated that the exposed larvae and adults could be controlled with a pyrethrum-oil spray consisting of from 0.004 to 0.005 per cent pyrethrins, either as a powder or extract, using 1 to 2 per cent of a light-medium grade summer oil (U.R. 92 or better). The addition of blood albumen at the rate of 4 oz. to 100 gallons of spray gave an increased wetting of the plants. Nicotine sulfate, rotenone, lead arsenate and cryolite did not give adequate control of the snapdragon plume moth in experimental work. The results of a spraying test conducted at San Leandro during October 1941 is shown in table 1.

Table 1.—Results of spraying tests for control of the snapdragon plume moth, applied with a power sprayer at 300 pounds pressure on October 4, 1941, at San Leandro, California.

MATERIALS USED	NUMBER OF LARVAE AND PUPAE ON 30 FLOWER STALKS ON OCTOBER 10	PER CENT REDUCTION IN NUMBER OF LARVAE AND PUPAE
Rotenone-pyrethrum-oil[1]	55	35.3
Nicotine-sulfate and oil[2]	48	43.5
Pyrethrum-oil (as extract, 0.01% pyrethrins)	26	69.4
Pyrethrum (as extract, 0.005% pyrethrins)-oil	26	69.4
Pyrethrum (as extract, 0.003% pyrethrins)-oil	37	56.5
Pyrethrum (as extract, 0.0025% pyrethrins)-oil	19	77.6
Rotenone (as extract in camphor-rotenone oil, 0.012%)	74	12.9
No treatment (checks)	85	—

[1] The concentrated mixture contained rotenone, 2.5%+7.5% resins, 0.4% pyrethrins, 15.5% petroleum oils, U.R. 92, emulsifiers, 36.6% and inert, 38%; used at the rate of 1 to 400. The oil used in this test and the following tests was a light-medium grade summer oil of U.R. 96%.

[2] The concentrated mixture contained petroleum oils, 31.76%, nicotine alkaloid, 2.07%, soaps, 11.50%, and inert, 54.67%; used at the rate of 1 to 50.

In addition to chemical control it was early apparent that the proper screening of the ventilator openings and of doors of the greenhouses combined with the careful screening of the small plants prior to transplanting would assist in preventing a serious infestation of the plants. In one instance it was possible to place the small plants in a cheese cloth covered enclosure inside a greenhouse when it was not possible to screen all the openings adequately.

Light-trap experiments carried on during September and October 1941 in which several different colors of monochromatic light were tried, including light and dark

Table 2.—Results of light trap experiments for the control of the snapdragon plume moth in a greenhouse at San Leandro, California, during 1941.[1]

Color of Light	Period Run	Average Sunset Temp. (° F.)	Number of Moths Captured				Proportion of Sexes Female-Male	Average Moths per Night per Trap
			Female	Male	Sex Undetermined	Total		
Light blue	Sept. 27 to Oct. 9	65.36	12	22	16	50	1–1.8	3.8
Dark blue	Sept. 27 to Oct. 9	65.36	11	11	10	32	1–1	2.5
Red	Oct. 10 to Oct. 18	62.87	7	34	3	44	1–4.8	4.8
Yellow-green	Oct. 10 to Oct. 18	62.87	18	34	9	61	1–1.9	6.7
White (50 W Mazda lamp)	Sept. 27 to Oct. 18	64.31	11	52	0	63	1–4.7	2.9

[1] The application of insecticides to the entire greenhouse on October 17 reduced the population of adults to such a low level that very few adults were taken at lights after this date.

blue, red and yellow-green in comparison with a white, *Mazda* globe, did not indicate adequate control through this means. The monochromatic colors were mercury discharge tubes used in an electrocuting type of trap as was used for the artichoke plume moth (Lange 1941). The 50 watt, *Mazda* globe was suspended over

FIG. 5.—Damage to snapdragon plants caused by the larvae of the snapdragon plume moth; A and E, uninjured plants, B, C, and D, injured plants.

a pan of oil to conform with the usual practice among snapdragon growers. No differences in the efficacy of the traps were found in adjusting the height from the ground between 2½ and 4 feet. The summaries of these light trap experiments are shown in table 2. These tests indicate that the yellow-green color attracted the largest number of females, followed by the light blue and dark blue colors.

THE CALENDULA PLUME MOTH.—The larvae of this plume moth have been found in California feeding on eighteen species of composites although globe artichoke, chrysanthemum, Michaelmus daisy and calendula are the only known food plants which are considered as being of economic importance.

Inasmuch as the article by Lange (1941) gives the more important features in the biology only those points will be considered which were not adequately presented at this time.

This moth is more closely related to the artichoke plume moth than to any of the other species under consideration, and the larval habits are very similar. The larvae may feed on any part of the calendula plants, but cause their most noticeable damage to the developing flower parts and the green seeds. These feeding habits greatly reduce the quantity of seed produced.

During 1937 at Half Moon Bay laboratory conditions where rearings were undertaken in Stendor dishes using pieces of calendula buds, the duration of time elapsing from the hatching of the eggs to emergence of the adults ranged from 38 to 43 days. The egg period varied from 7 to 10 days at laboratory temperatures and 8 to 10 days at outside temperatures.

No control measures for the calendula plume moth have been undertaken.

THE SAGE PLUME MOTH.—The sage plume moth is often a serious competitor to the honeybee as the larvae tunnel inside

the buds destroying the developing flower parts. Although it has been known in California for a number of years as the "sage worm,"[1] no previous records of its biology seem available.

This moth is widely distributed in California in the Sonoran and Transition life zones, with records from San Diego county in the south to Siskiyou county in the north. One record is available for its occurrence on Santa Catalina Island. In addition to California it is known to occur in Arizona, Colorado, Nevada, New Mexico, and Utah. Meyrick (1913) reports it from South America and the Hawaiian Islands.

The flower heads of this tall, perennial sage are literally riddled by the burrowings of the larvae.

The eggs of the sage plume moth are characteristic in shape, as one end is truncate and encircled by a ring of tubercle-like processes. Most plume moth eggs are elongate-oval in shape and lack processes. Eggs range in width from 0.18 to 0.31 mm. and in length from 0.53 to 0.57 mm., and are pale yellow in color. The egg is shown in figure 6 (inset).

Four larval instars occur. Fourth instar larvae have several color forms, but the green and reddish forms are the commonest. The larvae at the time of the

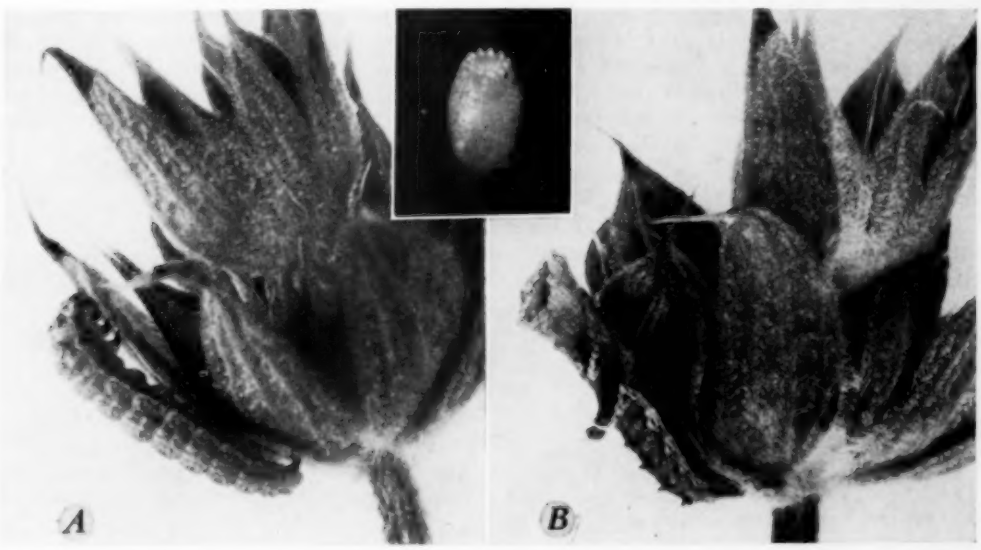

FIG. 6.—Mature larva, A, and pupa, B, of the sage plume moth, on a bud of *Salvia mellifera*, both ×5; also egg (inset) ×30.

The larval food plants which have been found in California include the following: *Agastache urticifolia* (Benth.) Ktze., *Mentha spicata* L., spearmint, *Mondardella odoratissima* Benth., *Pycnanthemum californicum* Torr., mountain mint, *Salvia carnosa* Dougl., *Salvia mellifera* Greene, black sage, *Salvia spathacea* Greene, crimson sage, *Scrophularia californica* Cham., California bee plant, and *Sphacele calycina* Benth., pitcher sage.

The most highly preferred food plant found by the writer was *Salvia spathacea*.

[1] The name "sage worm" should not perhaps be encouraged as other insects tunnel into the buds, including other lepidopterous larvae.

third molt are 7 to 8 mm. long, attaining a length at maturity of 11 mm. Regardless of the background color certain longitudinal lines are found; a dark dorsal line, two white, undulatory, lateral lines, and a white, subspiracular line. The head is green with darker blotches, the true legs and anal prolegs are black and the prolegs are concolorous with the underside of the body. The larva is shown in figure 6A.

The pupa is angulate, the color as variable as the larva and a conspicuous feature is the presence of a pair of dorsal arm-like processes as is found in *Platyptilia pica* (Walsingham). In all of the color variations there are indicated two an-

teriorly directed dark bands, the posterior bands extending from the base of the arm-like processes.

LIFE HISTORY AND HABITS.—The average time elapsing from the hatching of the eggs to the emergence of adults at Half Moon Bay for outside temperatures during February and March 1940 was 55.6 days. The larvae were reared on pieces of sage heads in Stendor dishes with white blotting paper on the bottom of the dishes to which water was added to maintain a high humidity. The egg stage varied from 7 to 11 days at laboratory temperatures. Adults were found to live from 6 to 52 days.

On *Salvia spathacea* in Monterey county where the life history has been more extensively studied, the larvae were found to be more or less external feeders on the small plants where they fed among the interfolded leaves of the terminal shoots. Later as the flower stalks appear the larvae become internal borers inside the buds and flower structures. A single larva can tunnel through several buds after which it seeks out a place to pupate either under the leaves or on any part of the flower stalks. The pupa is usually naked and hangs head downward from the plants. The pupa is shown in figure 6B.

Three generations a year were found on *Salvia spathacea* with some indication of part of a fourth.

The only observed parasite of the larvae was an ichneumon, *Posocentrus* sp., which was reared from larvae of the moth during April and May. A spider, *Hesperauximus sternitzkii* Gertsch preyed on larvae at Half Moon Bay.

No practical control measures for the sage plume moth are known at the present time.

Platyptilia pica (Walsingham).[1]—The larvae of certain races or subspecies of this insect occasionally select cultivated snapdragon and geranium (*Pelargonium* spp.). This insect is included chiefly so that it will not be confused with the snapdragon plume moth or other lepidopterous larvae feeding on these plants.

The food plants in the central, coastal part of California include many genera in the plant family Scrophulariaceae, a few in the Labiatae, and geranium in the family Geraniaceae. The genera of plants commonly selected include *Castilleia*, *Mimulus*, *Scrophularia*, and *Stachys*. The eggs are laid externally on the undersides of the leaves or on the terminal shoots or flower structures, and the larvae although they may occasionally become internal borers in the green seed pods of the plants involved are usually external feeders, webbing and feeding on the terminal leaves. The pupae occur naked and have peculiar arm-like processes similar to those of *P. fuscicornis* Zeller (although in other features the two species are not so closely related).

During 1937–38 the life history of *Platyptilia pica crataea* Fletcher at Half Moon Bay on *Scrophularia californica* from the time of hatching of the eggs to emergence of the adults varied from 36 to 65 days at laboratory temperatures and from 68 to 78 days at outside temperatures. Under outside conditions at Half Moon Bay, on the same host plant, there were found three overlapping generations a year.

No control measures have proven necessary for this insect up to the present time due to the occasional nature of the infestations. The braconid parasite *Apanteles insignis* Muesebeck is often very effective in parasitizing the larvae of this species in many California localities. During 1941 as high as 37 per cent of field collected larvae were found parasitized by this hymenopteran.—1–26–42.

[1] This name is used to replace two species, *Platyptilia acanthodactyla* (Hbn.) and *P. punctidactyla* (Haw.) The writer (Lange, ms.) has shown our North American species formerly going under these names to be referable to *pica* (Walsingham) and not to these European species.

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Damage to Highways by the Mound-Building Prairie Ant[1]

ROY F. FRITZ[2] and W. A. VICKERS[3]

While driving along the highways of central and western Kansas the motorist can not help but notice the large number of bare, cone-shaped mounds that dot the shoulder and the back-slope of the highway. These mounds are the nests of the mound building prairie ant, *Pogonomyrmex occidentalis* Cresson.

The mounds are in the form of elliptical cones of various sizes and heights depending on the age, size and location of the colony. The mounds are always near the center of an irregularly circular cleared space. In Kansas, the clearings are relatively small, the largest measuring approximately 150 to 200 square feet. (Fig. 1A). Nichol (1931) records clearings made by a closely related species of ant in Arizona that exceeded 1000 square feet in area.

The mound building prairie ant builds its nest throughout central and western Kansas. The eastern limit as determined by Headlee and Dean, 1908, reaches a line drawn between Belleville in Republic County and Oxford in Sumner County. The mounds may be found in nearly every crop and plant environment within their range, but are more prevalent along the roadways than elsewhere. There are probably three reasons for this. First, graders and elevators scrape away the vegetation when the road is built and the ants take advantage of this ready-made clearing in which to make their nests. Second, once the road is built these shoulders and backslopes are disturbed only rarely giving the nests an excellent opportunity to grow and develop unmolested. Third, food is abundant along the roadside where grain from passing trucks accumulates and where there is an abundance of weed seeds.

DAMAGE TO THE HIGHWAYS —Little attention has been given these ants along the roads and highways until the past three years. During this time the authors have observed considerable damage being done to the highways in western Kansas by these ants. The junior author, as landscape foreman of the Sixth highway division in southwestern Kansas, has had an excellent opportunity to study this damage.

In order to obtain data on this problem, questionnaires were sent to 27 Sixth Division sectionmen, each of whom is in charge of maintenance of an average of 35 miles of highway. All replied that the ant nests were numerous in their districts, the maximum number ranging as high as 150 per mile of road. The reports showed that from 25 to 100 per cent of the mounds were on the road shoulder. The number of nests was found to be increasing each year. The size of the clearing made by each nest was estimated to range from 10 to 150 square feet.

The major highway damage this insect causes is in connection with water erosion. During a heavy rain, water runs along the highway and great quantities run off over the cleared area around an ant mound on the shoulder where the soil is not protected by a cover of vegetation and bound together by weed and grass roots. This soil is easily eroded and after a heavy rain gullies several inches deep (Fig. 1B) can be found cut into the shoulder near each ant nest. Such gullies constitute a driving hazard if a car leaves the oiled surface.

It was also found that the ants often build their nests directly under the edge of the highway (Fig. 1B), weakening the highway base and causing the surface to sink or to crack and break up. All but two of the sectionmen reported this type of injury.

In 1940, approximtely 350 man-hours were required to repair the shoulders of 1500 miles of highway in the sixth division after each rain of more than a half inch. Labor alone for this job would cost approximately $175. There was an additional cost of $75 for operating trucks and equipment.

Much of the highway system in western Kansas is of oil penetration or oil mat construction. Nearly every rain erodes the shoulder of the highway and small particles of the oiled surface are crumbled away making it necessary to replace the edge of the surface with a patch after a time. In 1940 it was estimated that 300 patches

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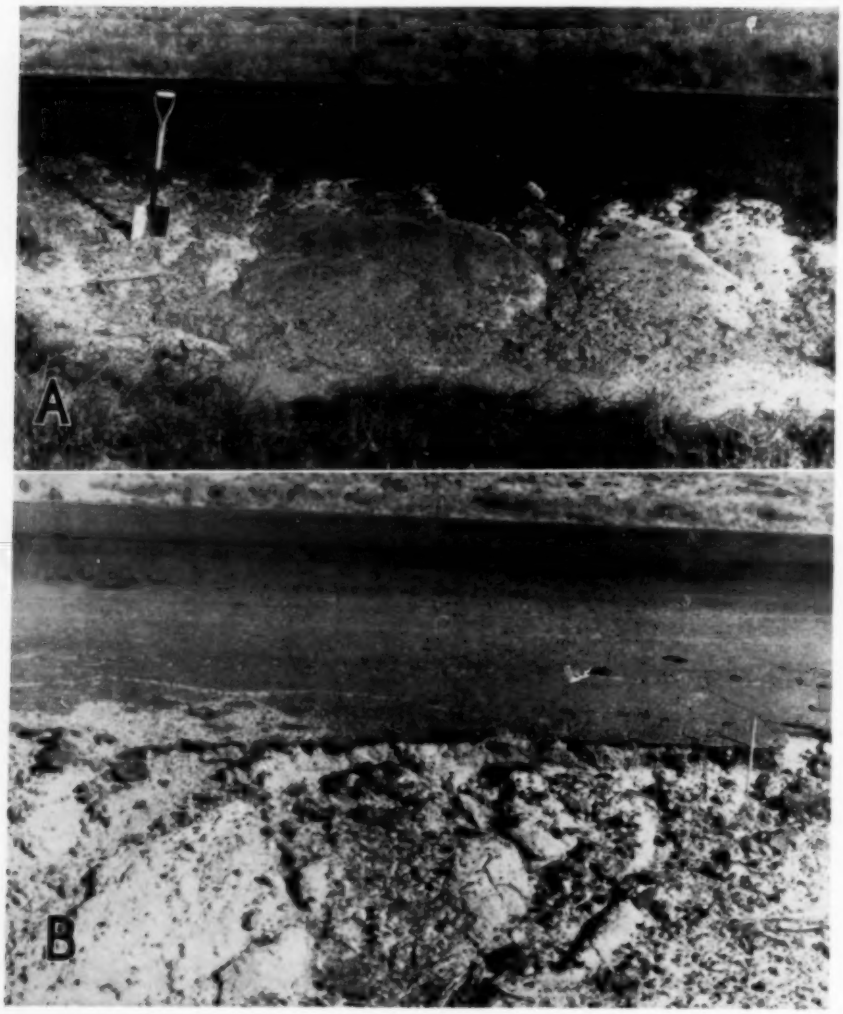

FIG. 11—A. Nest of the mound-building prairie ant on the shoulder of an oiled highway in western Kansas. Note the crumbing of the road surface caused by water erosion. B. Damage to oiled highway and shoulders caused by the mound building prairie Ant. The pencil at the edge of the highway (right) shows the depth of the erosion gullies on the shoulder. Gullies of this depth constitute a driving hazard The nest responsible for this erosion is just out of the pictured area at the lower right. The gravel thrown on the blacktop (left) marks a small ant nest directly beneath. Note the crack that has already developed in the oiled surface around this nest.

were required in the sixth division alone. Although the cost of the patches varies, depending upon size and thickness, highway officials estimate that an average patch would cost approximately $1.50. At this rate, the cost of repairing the damage to the highway surface in the sixth division amounted to approximately $450 in 1940.

DAMAGE TO GRASSES, SHRUBS AND TREES —During the past several years an effort has been made to beautify the Kansas roadsides by planting grasses, shrubs and trees. The mound building prairie ants have been destructive in many of these plantings within their range. The ants will not allow plants to send roots down through their mounds. As young grass plants and other seedlings appear above the soil surface, the ants actually tear them up.

METHODS OF CONTROLLING THE ANTS. —The method recommended by the Department of Entomology, Kansas Agri-

cultural Experiment Station (Headlee & Dean 1908) for the control of these ants is to evaporate 1 to 3 ounces of carbon disulphide under a galvanized tub which has been inverted over the openings of the mound. The use of a tub in fumigating the ant nests along the highway was impractical due to the large number of colonies that had to be treated and the risks involved in recovering the tubs.

This procedure was modified during the summer of 1940 to fit the highway problem. The measured amount of carbon disulphide was poured into openings in the mound. The mound was then immediately covered with several folds of newspaper which was then covered with soil. Two series of 25 nests were treated in this manner in a preliminary test of the method along the highways near Garden City. An examination after several weeks indicated that 70 per cent, of the treated nests had been destroyed.

At the beginning of the 1941 season the highway department purchased a quantity of carbon disulphide for use in combating the ants. To speed up the fumigating operation the junior author designed an "ant gun" using a discarded 3 pint fire extinguisher. A 12-inch length of copper tubing was soldered to the regular outlet of the extinguisher. The copper tube was closed at the outer end and several small holes were bored along the side near the tip of the tube.

In operation, the point of the tube was thrust through the crust of the mound until the point was among the galleries of the nest. This was easily determined by the ease with which the point passed through the mound. When the point was in the proper position, a stroke or two of the extinguisher handle would inject the fumigant into the nest. Large nests were dosed in more than one place. The gates of the nest were easily closed with a few shovelfuls of soil. The "gun" holds sufficient carbon disulphide to treat 15 to 20 ant colonies, depending on their size.

The control campaign in 1941 consisted of treating ant nests in 1- to 3-mile sections of highway near the county seats of eight heavily infested counties. The nests in these areas averaged 120 per mile of highway shoulder. When the treated nests were examined 2 weeks later, activity was found in an average of 25 per cent of the nests. These were retreated.

The best time to undertake a control program for these ants is early in the spring, after they have become active but before the colonies have reached full strength and before the swarming period. The colonies should be examined after an interval of 2 weeks and those in which ants are still active should be retreated. After the swarming period, an effort should be made to exterminate new colonies while they are still small and weak.

SUMMARY.—1. The mound-building prairie ant, *Pogonomyrmex occidentalis* Cresson, is abundant throughout central and western Kansas, especially along roads and highways; environments that are favorable to its existence.

2. Every year these ants do considerable damage to highway shoulders and surfaces because of their custom of clearing the shoulders of soil-binding vegetation and of building nests beneath the road surface. In 1940 the cost of highway shoulder repairs was approximately $250 in one highway division following every rain of more than a half inch. Highway patches made necessary by the work of the ants in the 1500 miles of highway in the division cost approximately $450.

3. Control of this ant can be accomplished by evaporating carbon disulphide under a galvanized tub inverted over the mound. Other methods are to use newspapers and soil to hold the carbon disulphide within the nest and to use a specially converted fire extinguisher to introduce the fumigant into the center of the nest. Surviving nests should be retreated after an interval of two weeks following the original treatment —6-1-42.

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Pollen Grains in Nectar and Honey[1]

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Three years ago we were attempting to stimulate brood rearing during the winter by feeding observation colonies with sugar sirup, but without success until we added pollen to the sirup, and then egg laying started within 12 hours. We repeated this procedure many times, with similar results. The reaction aroused our interest in the possible influence of pollen in normal honey and nectar on brood rearing, and we undertook a study of pollen grains in nectars.

Investigators who have made counts of pollen grains in honey have invariably found that many species of plants are represented, and that the predominating pollen is not necessarily from the main floral source. Koch (1933) reported some counts of pollen grains in the honey stomach of bees gathering nectar on 15 species of plants. He found that the pollen in the nectar was always that of the species being worked, that the amounts varied much with different plant species, and that the number of pollen grains varied greatly in 6 of the 15 plants examined in both 1932 and 1933. Cheshire (1886) stated that the collecting bee was constantly removing pollen grains from the nectar load in the honey stomach. Whitcomb and Wilson (1929) fed pollens in sirup and found that the pollen usually remained in the honey stomach less than 10 minutes. The pollen grains were rapidly drawn back into the ventriculus by the action of the honey stopper, while the sirup was retained in the honey sac.

METHODS OF COLLECTING NECTAR.—Nectar can be collected by pipette from plants yielding copious supplies, but many plants yield insufficient nectar per blossom to be so collected. Counts of pollen grains in nectar collected in this way have been possible in some instances, but it has usually been necessary to allow the bees to collect the nectar and the pollen count has been made from the contents of their honey stomachs. Bees work only one species of plant when on a pollen- or nectar-gathering trip. Comparisons of the pollen grains in the honey stomach with those of the plant on which the bee is gathering have almost invariably shown them to be identical, and only one species present. We are therefore reasonably certain as to the nectar source of the loads examined.

Bees in the process of collecting nectar were caught in a cyanide bottle, and immediately the honey sac was removed and the sac contents of one bee were placed in a haemocytometer, which was used for counting the pollen grains. Making counts immediately in the field minimized the time factor, which might reduce the pollen count. How long the bee had been collecting was unknown, but since a fairly full honey sac is required for a count many blossoms had probably been visited to obtain the load.

The hand-collection method (by pipette) is subject to the objections that pollen may be mechanically shaken into the nectar, and that all the nectar cannot be taken from the cup, as may be done by the bee. In the bee-collection method the bee may remove the pollen from the nectar load in the honey stomach, and it is not possible to know how long the bee has been collecting or the amount of pollen that may have been removed. Because of these limitations in obtaining samples, the data obtained must be interpreted with caution.

The haemocytometer was also used for counting pollen grains in hand-collected nectar. Pollen grains in five of the nine large squares were counted and from these data the thousands of pollen grains per cubic centimeter of nectar were calculated.

POLLEN CONTENT OF HAND-COLLECTED NECTARS.—Each sample of hand-collected nectar is a composite from several blossoms, except in the case of apricot, fuchsia, prune, orange, wax plant, and yerba-santa, where one blossom provided a sufficient quantity. The counts were found to vary widely between plant species. The number of samples and the mean pollen counts with their standard errors are given in table 1.

REMOVAL OF POLLEN GRAINS FROM THE HONEY STOMACH.—An experiment was made to determine the rapidity with which the pollen grains are removed from

[1] A contribution from the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, in cooperation with the University of California.

the nectar carried in the honey sacs of collecting bees. Into a 40 per cent sugar sirup was placed a quantity of pollen, and this material, freshly mixed with an electric beater, was placed in the feeder of an observation colony. Subsequently counts were made of the pollen grains in the honey stomach of bees that had fed there.

Table 1.—Pollen grains in hand-collected nectar.

Nectar Plant	Number of Samples	Thousand Grains of Pollen per Cubic Centimeter of Nectar (Means)
Cotton, *Gossypium hirsutum*	28	0
Cedar honeydew, *Libocedrus decurrens*	10	0
Fuchsia, *Fuchsia*, sp.	20	0
Wax plant, *Hoya carnosa*	50	0
Navel orange, *Citrus sinensis*	11	0
Black locust, *Robinia pseudoacacia*	6	1.67±0.61
Apricot, *Prunus armeniaca*	21	6.75±0.99
French prune, *Prunus domestica*	110	7.09±0.57
Plum, *Prunus* spp.	169	10.94±0.82
Valencia orange, *Citrus sinensis*	17	25.00±3.43
Yerba-santa, *Eriodictyon californicum*	21	26.19±3.62
Manzanita, *Arctostaphylos pastillosa*	32	28.75±4.18
Manzanita, *Arctostaphylos viscida*	10	49.50±10.2
Avocado, *Persea americana*	140	55.00±2.10
Manzanita, *Arctostaphylos patula*	28	73.57±8.69
Willow, *Salix* spp.	13	80.00±1.96
Filaree, *Erodium cicutarium*	8	111.25±12.0

Some bees were dissected immediately after feeding, while others were held 15 minutes before they were examined. Bees examined immediately invariably showed high pollen counts in the contents of the honey stomach, while most of those held for 15 minutes showed a drastic reduction in pollen count (Table 2).

In another experiment three observation colonies were supplied with ample pollen reserve in the form of pollen paste but were deprived of stored honey. They were fed, from trays within the hives, clear sugar sirup, dilute star-thistle honey, or sugar sirup with 3 grams of pollen added to each 100 cc. Pollen counts of these materials were made before feeding. These liquids were then stored and sealed by the bees. Later the combs were removed and counts made of the pollen grains in the cells. These data, which are shown in table 3, also indicate that a marked reduction in the pollen content occurred between the gathering and the sealing of the liquid materials in the cells.

Table 3.—Number of pollen grains in three types of food before feeding and after storage by the bees.

Food	Thousands of Pollen Grains per Cubic Centimeter	
	Before feeding	After storage and sealing
Clear sirup	0.0	0.1
Dilute star-thistle honey	5.2	1.2
Sirup and pollen	750.0	25.3

From these experiments we should not expect counts of the pollen grains in the contents of the honey stomach to be an accurate measure of the pollen in the original nectar. We should expect such counts to vary with the length of time that the bee has been collecting. When a long time is required for a bee to get a load of nectar, there is more opportunity for the pollen content to be reduced than when the bee can get back to the hive quickly.

COMPARISON OF SAMPLES COLLECTED BY HAND AND BY BEES.—Pollen counts of nectar collected by hand and by bees from the same plant species were made in a few cases (Table 4). The hand-collected nectar

Table 2.—Frequency distribution of number of pollen grains in honey stomach of bees 15 minutes after feeding as compared with the number immediately after feeding.

Test No.	Immediately after Feeding. Thousands of Pollen Grains	15 Minutes after Feeding. Number of Bees in Class Group with Indicated Range in Number of Pollen Grains					
		0–20 thousand	21–40 thousand	41–60 thousand	61–80 thousand	81–100 thousand	Over 100 thousand
1	184–200	2	2	0	2	0	0
2	206–254	12	3	4	1	0	0
3	310–338	7	2	4	2	1	6[1]
Total		21	7	8	5	1	6

[1] 116, 130, 154, 158, 228, 258 thousand pollen grains.

Table 4.—Comparison of pollen counts in nectars from nine plants when collected by hand and by the bees.

Plant Sources	Thousands of Pollen Grains per Cubic Centimeter of Nectar (Means)	
	Collected by hand	Collected by bees
Cotton, *Gossypium hirsutum*	0	0
Navel orange, *Citrus sinensis*	0	0
Black locust, *Robinia pseudoacacia*	1.67±0.61	2.67±0.62
Apricot, *Prunus armeniaca*	6.75±0.99	4.84±2.91
French prune, *Prunus domestica*	7.09±0.57	2.41±1.02
Plum, *Prunus* spp.	10.94±0.82	2.97±0.75
Valencia orange, *Citrus sinensis*	25.00±3.43	6.77±0.62
Yerba-santa,[1] *Eriodictyon californicum*	26.19±3.62	61.11±5.92
Willow, *Salix* spp.	80.00±1.96	47.78±5.24

[1] The tubular blossom was pulled out and the nectar removed from the slit-open blossoms. The collecting bee reaching through the stamens would probably shake more pollen into the nectar than would hand collecting.

shows considerably higher pollen counts in most cases, as would be expected from the previous experiments. Bee-collected nectar may be used to obtain only a rough index of the relative amounts of pollen in various plant species.

Pollen Content of Bee-Collected Nectars.—Pollen counts have been made in bee-collected nectars of 73 kinds of honey plants in California. The average counts show a fairly continuous series from 0 to 66 thousand pollen grains per cubic centimeter of nectar, and two plants giving higher counts (Table 5). A wide range in the number of pollen grains was found in the samples from any one species, but the average counts are indicative of the relative rating of the plants concerned.

Table 5.—Pollen content of bee-collected nectars, arranged in order of increasing number of grains.[1]

Plant Source	Number of Samples	Thousand Grains of Pollen per Cubic Centimeter of Nectar (Means)	Notes on Other Nectar Characteristics
Cotton, *Gossypium hirsutum*	32	0	
Navel orange, *Citrus sinensis*	30	0	
Cedar honeydew, *Libocedrus decurrens*	—	0	
Fireweed, *Epilobium angustifolium*	27	0.22	
Flax, *Linum usitatissimum*	13	0.31±0.20	
White sage, *Salvia apiana*	50	0.80±0.72	Bubbly
Bluecurls, *Trichostema lanceolatum*	49	0.90±0.20	Bubbly
Desert buckwheat, *Eriogonum fasciculatum* var. *polifolium*	78	1.39±0.22	Pronounced odor
Peach, *Prunus persica*	20	1.80±0.41	
Morning glory, *Convolvulus arvensis*	41	1.76±0.31	Yellowish
Quince, *Cydonia oblonga*	28	1.93±0.21	
Avocado, *Persea americana*	18	2.00±0.65	
Hairy vetch, *Vicia villosa*	25	2.16±0.52	
Spikeweed, *Hemizonia pungens*	20	2.40±0.57	Yellowish
Prune, *Prunus domestica*	84	2.41±1.02	Light amber
Black sage, *Salvia mellifera*	33	2.43±0.27	
Purple sage, *Salvia leucophylla*	57	2.56±0.42	
Catalpa, *Catalpa speciosa*	58	2.62±0.55	Cloudy
Black locust, *Robinia pseudoacacia*	21	2.67±0.62	
Spikeweed, *Hemizonia fitchii*	18	2.78±1.04	Yellowish
Lippia, *Lippia canescens*	38	2.89±0.39	Bubbly
Milk thistle, *Silybum marianum*	37	2.92±0.59	
Plum, *Prunus* spp.	29	2.97±0.75	
Red filaree, *Erodium cicutarium*	42	3.25±0.79	
Chamaebatia, *Chamaebatia foliolosa*	60	3.60±0.53	Yellowish
Alfalfa, *Medicago sativa*	114	3.79±0.44	Colorless
Thistle sage, *Salvia carduacea*	6	3.83±1.04	
Flat-top buckwheat, *Eriogonum fasciculatum*	67	3.85±0.31	Pronounced odor
Cherry, *Prunus avium*	111	3.95±0.51	Light amber
Wild alfalfa, *Lotus scoparius*	32	4.38±0.61	
Creeping sage, *Salvia sonomensis*	20	4.70±0.77	
Apricot, *Prunus armeniaca*	19	4.84±2.91	
Purple vetch, *Vicia atropurpurea*	28	6.07±1.17	
Privet, *Ligustrum* sp.	31	6.13±1.15	Bubbly
California bay, *Umbellularia californica*	6	6.33±2.04	
Valencia orange, *Citrus sinensis*	47	6.77±0.62	
Rabbitbrush, *Chrysothamnus nauseosus*	38	7.10±1.13	Variable, yellow to white

PLANT SOURCE	NUMBER OF SAMPLES	THOUSAND GRAINS OF POLLEN PER CUBIC CENTIMETER OF NECTAR (MEANS)	NOTES ON OTHER NECTAR CHARACTERISTICS
Toyon, *Photinia arbutifolia*	42	7.14±0.64	Greenish yellow
Nemophila, *Nemophila* sp.	15	8.00±2.02	Cloudy
Phacelia, *Phacelia tanacetifolia*	5	8.80±1.62	
Redmaids, *Calandrinia caulescens*	38	9.05±1.01	Orange
Chickweed, *Stellaria media*	6	10.00±1.11	
Ladino clover, *Trifolium repens*	34	10.29±0.96	
Black mustard, *Brassica nigra*	36	11.94±2.15	Bubbly
Dandelion, *Taraxacum officinale*	61	12.26±1.87	
Pear, Winter Nelis, *Pyrus communis*	37	12.30±2.28	
Wild plum, *Prunus* sp.	7	12.85±4.72	
Onion, *Allium cepa*	21	13.33±1.58	
Apple, *Pyrus malus*	75	13.80±1.73	
Hoarhound, *Marrubium vulgare*	50	13.92±1.53	Bubbly, colorless
Blue gum, *Eucalyptus globulus*	45	15.20±1.82	
Tamarisk, *Tamarix articulata*	30	18.00±1.36	Greenish
Oxalis, *Oxalis* sp.	13	19.23±5.71	Yellow
Cascara, *Rhamnus californica*	29	20.17±2.57	Slightly yellowish
Genista, *Genista monosperma*	20	21.11±2.47	
Charlock mustard, *Brassica kaber* var. *pinnatifidum*	57	21.52±2.35	
Raspberry, *Rubus occidentalis*	18	21.67±1.15	
Star thistle, *Centaurea solstitialis*	25	24.00±3.57	Greenish
Buckeye, *Aesculus californica*	48	24.69±2.97	
Blackberry, *Rubus procerus*	22	33.64±4.29	
Asparagus, *Asparagus officinalis*	21	33.81±8.33	
White sweetclover, *Meliotus alba*	77	41.04±4.11	Bubbly
Dutch clover, *Trifolium repens*	56	45.00±3.62	
Wild radish, *Raphanus sativus*	14	47.50±8.87	
Willow, *Salix* spp.	27	47.78±5.24	
Carrot, *Daucus carota*	30	52.33±4.76	
Grape, *Vitis vinifera*	41	55.61±3.21	
Yerba-santa, *Eriodictyon californicum*	27	61.11±5.92	
Turnip, *Brassica rapa*	18	61.66±7.89	Bubbly
Alsike clover, *Trifolium hybridum*	46	64.78±7.13	
Amsinckia, *Amsinckia* spp.	46	66.52±5.82	
Common mustard, *Brassica campestris*	23	86.52±8.56	Bubbly
White mustard, *Brassica alba*	24	103.33±9.86	Bubbly

[1] Counts for fireweed, alsike, and hairy vetch nectars were made by H. A. Scullen, of Oregon State College.

The samples from a given species invariably showed only pollen grains from that plant. The nectars were colorless, with the few exceptions noted. Honey stomachs containing yellow liquid were brought to the laboratory for examination. The colored material accumulated at the top of the liquid upon standing, and proved to be pollen grains. Amber liquid did not clear. A few species, notably mustards, invariably gave bubbly samples, indicating that air had been drawn in with the nectar by the bee.

Whether there is any correlation between the pollen count of nectars and the level of egg laying has not been determined, although egg-laying levels vary in the course of a year. High levels are associated with flows from mustards, manzanita, and sweetclover; and low levels with flows from orange, bluecurls, and buckwheat. These groups of plants appear to vary widely in the pollen content of their nectars. If there is a correlation the pollen count of honey may influence its value for wintering purposes.—4-27-42.

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The Needs of Systematic Entomology[1]

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Any attempt to arrive at an understanding of the present status and the needs of systematic entomology must take into consideration something of the history of biological systematics in general.

The very first consideration is the simple fact that by far the greater part of all systematic work in all biology has been accomplished by people who were in no way recompensed for their efforts except through such intellectual satisfaction, or pride in achievement, or inflation of their ego or increased prestige or other non-tangible return as they may have been able to gain from it. Far from returning money or goods of any kind to them, such work has in fact cost many systematists money as well as effort.

Now, of course, such has been the condition with many of our very finest of human activities. Many an artist has starved while striving to satisfy an inner urge and without thought of any material compensation. Whatever this compulsion may have been, and however incomprehensible it may be to those who have never felt such an urge, however close it may have come at times to being actually psychopathic, the fact remains that we owe a very large part of all cultural advancement to it. Apart from the painter and the musician, there have probably been but few avenues of endeavor in which the prospect of material return has meant less than it has for the systematist. His work, in the main, has been done entirely without that thought of eventual success and affluence which even the most disinterested of artists has probably never completely dismissed from his mind. The artist may achieve affluence, the systematist cannot hope ever to do so, at least as a systematist. Apart from the very few none too munificently paid positions in museums which might be gained as the reward for prestige achieved or ability demonstrated in the course of systematic studies there has up to very recent years been nothing but these subjective satisfactions to stimulate the systematist.

Under these conditions systematic work has in the main been essentially an avocation, pursued with a degree of assiduity ranging from merely casual interest up to full time activity on the part of those who were so fortunate as to be financially independent and so peculiar as to be willing to devote their whole effort to such work.

Of recent years a few people have actually been paid cash money for their activities as systematists, but the number of these is still both actually and relatively small. It must be borne in mind that most of the positions for which salaries are paid to systematists and ostensibly for systematic work do not actually permit much real systematic work to be done.

Systematic work in entomology is not merely sticking pins through insects and then arranging them in boxes, with the subsequent watchman's rounds of the collection to frustrate the dermestids that seek to break in and destroy. Nor, any more so, is it merely the making of identifications and the affixing of labels to such collections. Nor is it the writing of letters to people who want to know what the insect is that is eating up their garden. Nor is it merely the teaching of elementary students to recognize a grasshopper when they see one. But these are the primary activities in many paid positions held by systematists. The total number of people who are paid to do actual systematic work in entomology is infinitesimally small. I doubt if there are even ten such positions in the United States.

One of the greatest needs of systematic biology is to blast out of our thinking the idea that the making of identifications is the be-all and end-all of systematic work, the idea that if you put a name to a specimen you have done all that a systematist is supposed to do. The making of identifications and the putting of names on specimens is—or should be—only the terminal and more or less incidental and automatically achieved by-product of preceding investigations directed toward the development of an understanding of the biological situations involved in the question as to whether various organisms are or are not of different species and as to how those species can best be treated to

[1] Paper from the Taxonomy Symposium, Pasadena, 1941.

bring out the body of fact that is associated with them. Such work may—and in many cases must—involve even long and laborious experimental investigations before it comes finally to the point where the question of how to identify—or tell some one else how to identify—species or the question of what name should be applied even arises.

I repeat that the total number of people who are paid to do real investigational work—research—on the systematics of insects is infinitesimally small.

I, for example, am not paid to do systematic work in entomology. I am paid, presumably, to teach entomology, but having only a small number of students I have to do something to justify my existence—if not my salary—and so I work on the systematics of scale insects and some other things. It could just as well be something else, or—I might remark, with a cynicism engendered by about thirty years of academic life—it might almost as well be nothing at all, if that nothing can be inflated to look like something. A distinguished fellow worker in the same special field, is not so fortunate. His unquestionable capacities as a research worker are to a great extent smothered under the burden of routine identifications that must daily be ground out of his office. But there ought to be in the world at least a half dozen equally qualified individuals who are devoting their entire time to the systematics of this group.

Now this situation is responsible both for the development of systematic entomology to what it is, and for the limitation of systematic entomology to what it is. The conditions are by no means an unmixed good; they are by no means an unmixed evil. What we have lost in one way we have gained in another. Or to reverse the emphasis, what we have gained in one way, we have lost in another.

In the first place, if it had not been for this volunteer effort, we would still know very little about the systematics of insects. It is this effort that has actually given us what we have. And for that, we should be properly grateful.

But to a most unfortunate extent, this volunteer effort has not given us the quality that we now need, and we have reached the point where in at least many groups quality is above all the characteristic that is desirable in systematic work. There have been named and briefly described, for example, somewhere between 2500 and 3000 species of scale insects. But the vast majority of these are merely names with a most uninformative description attached. Most of these descriptions tell us nothing except that a species which belongs in a certain roughly and frequently erroneously indicated group occurs in a certain region. And what actual good does that do us? It is only the even yet comparatively small number of species which have really been investigated and properly described and figured and assigned to the group to which they really belong that give us any of the information as to hosts and distribution and places of origin which we must have if the systematics of the scale insects is actually to contribute anything to knowledge and understanding. And the same thing is true in almost any group that one may select, although in some the conditions are probably better, while in others they may even be worse.

The plain facts are that the urge for accomplishment has, among systematists dominated by the avocationist point of view, been too easily satisfied by holding up to view "One hundred new species of the genus So and so" the descriptions of which consist of little more than a name and a locality record. The feeling that the duty of the systematist is to bring to light as many new species as possible has fitted entirely too well into the avocationist philosophy.

This is not to say that there has been no good systematic work done under this system. Almost all good systematic work that we have—like the greater part of all systematic work, good and bad—has come out of its activities. But this good work has come more or less as an accident through the purely chance occurrence or activity of some individual who had the particular qualifications and the particular opportunity for work which enabled him to escape from the standard mold.

While the intentions of entomological systematists have usually been thoroughly good, their execution has frequently been exceedingly bad, chiefly because of their fundamental philosophy, the lack among many of them of anything that can by any stretch of the imagination be called scientific training or a scientific point of view, and the lack of effective

criticism arising either from themselves or from others.

One other difficulty inherent in systematic work on insects is the fact that there are too many insects. This circumstance has affected us in several ways. On the one hand it has stimulated the belief that the principal duty of the systematist is to find and name new species, thus leading to quantity rather than quality of production. The fact that so many species exist combines very nicely with the desire to attach names to as many as possible of them. And the fact that so many species exist makes it necessary first to describe and name large numbers of them before we can go on to anything else. What should be merely reconnaissance activities become finally the chief project to which all attention is directed.

And the fact that there are so many insect species makes it virtually impossible to cover all the groups adequately, even by the most enthusiastic effort, volunteer or otherwise. There are many groups about which we yet know almost nothing, some of them groups so unattractive that a person working merely for pleasure is not likely to pay much attention to them. Such, specifically, has been the case with insect larvae in general. What attraction was there to lead anyone to devote himself voluntarily and spontaneously to such forms, which have to be kept in bottles, which are not beautiful and do not make cabinet specimens, which require special techniques of collecting and rearing and preparation for study? The result has been that when within the last few years a recognition of the need for knowledge of the systematics of insect larvae began to develop almost the whole business had to be built up from the very beginning. Yet a knowledge of the systematics of the larvae of many insect groups is just as important as a knowledge of the systematics of the adults and to ignore them—as has been done—is entirely an unsound procedure. For once the need of paying someone to do a bit of this work as part of a program seems finally to have been realized.

Possibly in part as a result of some of the conditions which I have been describing, but also undoubtedly in part as a result of those characteristics of human behavior which lead our thinking on almost every subject to swing from one extreme to another, there developed at one time a certain contempt on the part of many biologists for systematists and their work. In part I think that contempt was justified, for undoubtedly much systematic work has been no better than childish. In part, however, it was merely an expression of certain normal processes of development. It is quite a common thing to find in young people the tendency to develop a degree of dissatisfaction, at times becoming contempt, for their predecessors—or even their progenitors who stand in the relation of the F generation to them. These predecessors and progenitors seem, to the new-found sophistication of the F_1 and F_2 generations, to be incredibly naive and unprogressive. By the time the F_3 generation has been reached a reaction may set in and the predecessors and progenitors may even begin to take on a heroic aspect.

Such, in some degree, has been the story of the development of biology. As each new field of activity has developed, those slightly gray-bearded ancestors, systematics and morphology, have to the younger descendants taken on the appearance of doddering senility and there have at times been pointed suggestions that their day is over and they might just as well move into the chimney corner and keep out of the way. The concrete results of this are that while anyone who calls himself an experimentalist can secure aid to buy any toy that he may need for his work, the systematists are left pretty much out in the cold when the annual distribution of largesse is made by those Ladies of the Manor, our national foundations for the support of research. One great foundation which has contributed to experimentalists sums that a systematist can only regard as fabulous, specifically indicates that requests for aid in systematic work will not be entertained.

And then there is the perennial problem of publication. While even yet the greater number of our entomological journals are devoted to the publication of systematic papers, the situation is by no means so favorable to systematists as it might appear to be. In fact the conditions are actually deleterious to good systematic work.

In the first place the greater part of our entomological journals are actual or spiritual products of the period and of the

type of activity that I have described earlier in this paper. They were established and are maintained by the volunteer efforts of individuals to many of whom entomology is primarily an avocation. While on the one hand this has resulted in the publishing of most of the entomological information that we have it has on the other hand kept the standards of these journals to the level of those who have supported them. There are a few journals which can afford to set and maintain a high standard, but even in the best of these you will see papers which will not bear critical examination.

Another concomitant of the present system is the fact that while we have numerous journals most of them are actually very small and are poverty-stricken. Very few of them can afford to take papers of the large size and monographic nature which are what we really need and so a very large proportion of the published material is in the form of very small papers and to a large degree devoted to the description of more new species. Now you can put the brief description of two or three or perhaps half a dozen new species into such a paper, but you cannot treat a whole genus or a whole tribe comprehensively. Yet these treatments of larger groups are what we need above all, the new species that may appear in the course of the work taking their proper places as merely incidental to the development of the study.

This situation illustrates one of the most discouraging problems with which the systematist has to contend. That is the utterly trifling, the unspeakably piddling, way in which we have to work. What is the use of doing a well rounded, well illustrated, complete and polished piece of work if there is no way to get it published after it is done? It does no one any good if it remains shut up in a drawer for the next ten years. And so we are impelled to produce little papers of four or five pages in endless padding of our bibliographies.

In connection with this matter of publication there is one other difficulty that appears with painful prominence. This has to do with the publication of illustrations. I do not believe that a single entomological journal in this country handles this problem in a manner calculated to promote the best interests of systematic entomology. There are perhaps some groups of insects the systematics of which can be presented adequately without the aid of any illustrations, but I don't personally know what those groups are. I have never found any of them myself. In all the groups with which I have worked, figures seem to me to be indispensable. But our entomological journals almost without exception penalize the worker who makes use of illustrations by requiring him to pay all or at the best a substantial part of the necessary extra cost involved in including figures when the ordinary methods of printing are employed. And I say bluntly that descriptions of such things as the scale insects and as the ectoparasitic insects with which I have worked are not worth publishing unless adequate illustrations are included. And by that I mean illustrations that are really adequate, not the childish attempts at drawing that seem to indicate the limits of capacity of entirely too many systematists working even today.

This, then, is the condition of systematic entomology as I see it, this condition arising in the main out of the nature of its historical development. What, in the light of this, are the needs of systematic entomology and how are those to be met?

It is much easier to answer the first part of the question than to answer the second part. The needs are obvious. The remedies possibly do not exist or if they do exist they may be inapplicable practically or perhaps they may eventually become effective only after most of us here beyond worrying about such things.

One of the primary needs is a different philosophy underlying our systematic work, or at least underlying certain portions of it. As I have pointed out, the very richness of the insect fauna of the world has in the past been a disadvantage. Perhaps that disadvantage can be converted into an advantage. There are enough groups and species of insects so that there is room for the activities of innumerable people with different points of view. Perhaps the systematics of insects can to some extent be divided up into spheres of influence. There are certain groups which are of very great importance to man. In connection with these we need systematic work in which the standards of even the most enthusiastic and well meaning avocationist are not adequate. Here we need work that is done not merely because

some one derives an esthetic pleasure or personal gratification out of it and spontaneously volunteers to do it. Here we need work that is governed by professional standards because it is a part of a scientific program. As a part of such a program it must measure up to the same standards as do the other parts. It must be able to bear tests and to bear criticism, it must be based upon sound principles and sound procedure. It must be so done that it affords a reliable basis for the other types of work that must rely upon it. Under these conditions it is no task for the avocationist. Such work requires a professional point of view, a philosophy, which is very different from that which has controlled the greater part of our systematic work in the past.

But after all, only a comparatively small proportion of all the insects are thus of direct importance to man. There are uncounted thousands of others and we need to know something about them. They should not be ignored, for if they were our outlook on entomology would be limited indeed. There are in fact so many of these insects that if we are to know anything at all about them we must depend upon the activities of those who approach their work purely from the stimulus of personal interest and the pleasure which they receive from it. If such workers were to disappear entirely from the picture we would lose greatly thereby. Even the highly technical science of astronomy makes use of its volunteer observers as contributors to the great program of study of the variable stars. And so there should be a place in entomology where any reasonably competent worker can find something worthwhile to do.

I suspect that something of this sort will develop as time goes on. In fact there are various groups which are becoming too difficult for anyone without extensive equipment in training, in instruments and in library and as these groups increase the avocationist fringe is automatically squeezed out and will turn its attention to something else.

Correlated with this is the necessity for improved training of systematists. There has in the past been the feeling that a systematist needed no special training. He needed only—like the priests of primitive cults—to feel the call to serve. After all, anyone could look at an insect through a hand lens or a low power microscope, run it down in a key after learning a limited technical jargon, or compare it directly with others of the same group and if it didn't fit the keys or descriptions or if a counterpart for it could not be found in collections he could describe it as a "species new to science." That is all there has been to much that has passed as systematic entomology, and for that indeed no special training was necessary.

But that is not all there is to it.

Take the apparently simple matter of using the microscope. I work especially in groups which require training in the use of this instrument, that is in the capacity to see minute structures and to appreciate and interpret what one sees. I have rarely had a student who at the beginning of his graduate work—regardless of the university from which he came—could really see things properly through a compound microscope. And I may add that the published work of Ph.D.'s throughout the United States and of men of even long activity indicates that at times this condition extends past the graduate years. Our usual undergraduate training is too hurried and entirely too superficial to develop such a capacity. Yet our systematic work is coming more and more to the necessity of seeing and utilizing the structures of microscopic size.

Along with this goes, according to my lights, the necessity of being able to produce drawings of good professional quality and the understanding of what a drawing of good professional quality is. I consider ability as an illustrator to be part of the equipment of the professional systematist. Our students need better training as draftsmen.

So much for technique alone, although that is not all that could be said about it.

We need better indoctrination of our systematists in biological concepts. A species is not merely a specimen on a pin or on a slide or in a bottle. These specimens are merely samples, most inadequately representing a population of perhaps millions of individuals, a population with certain biological as well as morphological characteristics, with certain capacities, with certain behavior patterns. These as a whole are the things that make up the species, that in the end are significant and our specimens in the museum can at the best serve merely as index guides which if

properly arranged and interpreted may help in leading us to the reality. And let me remark that, biologically, species are a reality and not merely a concept of systematists.

And classification is not merely a matter of convenience. It should be an attempt to reveal facts and their proper relation to each other, a relation that depends upon the way in which evolutionary processes have operated. The scale insect genus *Aonidiella* when properly understood is not merely a group of species thrown together for convenience of identification. Nor is it merely a concept. It is a group of species, expressing a common pattern of structure and a pattern of distribution a pattern which when once clearly seen reveals facts of great potential importance to economic entomologists when they see fit to use them. The appreciation of such a doctrine is something that has to be developed, it does not arise spontaneously in the untrained mind.

We need the development of a different point of view in regard to publication, a point of view that will lead eventually to the elimination of the trivial and useless and that will encourage and support the publication of material that is important and significant. This should not be by any placing of tyrannical power in the hands of editors but by a building up of standards such that a contributor to a journal would be ashamed to submit such childish material as much which encumbers the past volumes of our entomological journals. And we need some one to fathom for us the secret of how the Germans were able to publish such pretentious and apparently economically impossible—and at the same time such colossally bad—works as those which at one time issued in such numbers from that nation. If we could fathom that, perhaps we could find a way to publish really good comprehensive works in the United States.

We need a willingness to employ new methods of printing. Some of these new methods reduce the cost of a page of figures to less than the cost of a page of text. The editor of a journal printed by these methods is forced to develop a new set of values. Instead of resenting every figure that accompanies a paper he will resent every page of text, and in the end he must learn to strike a proper balance between the two. One difficulty, however, is that the editor of a journal printed by these methods must have power to control rigidly the form in which papers must be prepared, for otherwise the economies inherent in the method cannot be achieved. The contributors must have a better understanding of what is required than most of them now have. Using these methods of printing I have been able to publish 500 copies of a paper containing 76 pages, including 64 full pages of figures, at a total cost of slightly less than $175.00. It was a paper of a length that almost no journal in the land could have accepted and if any journal had accepted it I would have been required to find at least $350.00 in order to pay for the blocks for the figures alone. It is only where a large proportion of figures is used and where the figures are specially prepared for publication by this method that such economies can be gained. They would not be entirely attainable in a general journal.

But with all this, there still remains the problem of the systematist himself, of how he is going to get an opportunity to work. Research of the quality that is needed now in many areas of systematic entomology cannot well be done by some hardworked doctor, or policeman, or janitor or gardener, or even by every college professor, who in his few spare moments of relaxation after having earned his daily wage whiles away time with his collection of insects. The days when that could be done are passing. Systematic work of the kind that we need now most of all is a full time job for a trained professional who has the technical facilities that are needed and who, through the help of assistants, is freed from the pressure of routine so that he can concentrate upon his essential task.

How many such positions are there?

At this point I am going to lay down the law bluntly to the economic entomologists.

If you have at times been disgusted with the inadequacies of our systematic work; if you feel that it should be done better than it has been done; if you want it done in such fashion that it affords you the help that you need in your work;—then it is up to you to do something about it. As long as you go on cadging your systematic work from systematists like a panhandler cadging dimes or cigar butts, dimes and cigar butts are all you are likely to get. If you don't like the way our sys-

tematic work has been done, just reflect that it has never cost you anything. It has been a gift, and if the gift has not been adequate or satisfactory you can't very well complain. How many of you have not had the experience of wanting an identification of some insects? You have sent specimens either to some private worker or to the official systematist of your bureau or department. The private worker is slow about answering—remember he doesn't have an office staff to look after correspondence—and maybe he doesn't answer at all, being immersed in other things. If you sent them to your official expert, you may have received a definite identification within a reasonable time or you may, even more often, after the lapse of weeks have received a notation to the effect that the species seems to belong to the genus So and so, near such and such.

But what do you expect? No systematist can make identifications quickly and definitely in any group until a large amount of background research has been done. There is no man in the world who can give you a definite identification of any but perhaps a dozen common species of mealybugs. To go any further than that requires that someone shall sit down to an investigation of the systematics of the family Pseudococcidae for the whole world, not just of some small area, or not just of a few species. It will require at least three years of steady, laborious, eye-straining work before the business will be in any shape at all, and if he has it anywhere near done in that time he will have to work rapidly and efficiently and have adequate help in the form of assistants to make slides for him.

Then, with this work done, with the resulting paper, amounting to two fat volumes, on the mealybugs of the world ready for publication so that the work will be available for general use, all the systematist will have to do will be to hunt around for some way of publishing it and in the end either dig up out of his own pocket, or pare the paper down until it is emasculated or file it away to become obsolete. A government that will throw around billions of dollars on projects that have political significance will gag at spending a couple of thousand dollars to publish such a work as this. No private publisher will touch it, for there is no hope of a profit. The number of foundations that will grant money in sufficient amounts for the publishing of such a work is exceedingly limited.

And yet it is work of this sort that we need above all. That is the way it should be done. That is the scale on which systematic entomology that is going to produce something worth while should be conceived and executed.

But how is this to be done? We have a few government and institutional paid positions the holders of which are given some opportunity to do a limited amount of research in systematic entomology. But let me emphasize again the fact that the grinding out of endless routine identifications is not research in systematics. The actual total of research issuing from such positions is exceedingly small. And when the holder of one of them does manage to get something completed he is not much better off than anyone else in the matter of publication.

One of the greatest needs in systematic entomology is that those to whom good systematic work is a basic need should do something to encourage and support the carrying on of such work, to recognize that research in systematic entomology is just as necessary as research in insecticides or physiology or life histories. It cannot be done without support. It cannot be done if it is left entirely to the chance that some individual will combine the initiative, the time and the money—and be willing to use all of them—to do it for you. There should be some sort of a program that takes care of these matters and there should be some stimulus which will induce competent young investigators to undertake the work of such a program. The best they can hope for now is a chance at one of the few positions which offer some little opportunity to do research after they have ground out their daily quota of identifications, or have pinned their proper number of insects for the day, or have finished their stint of applying insecticides to experimental plots of peas or whatever it may be. Not a very attractive prospect, but the best there is.

Just what can be done about it, I am unable to say. Probably nothing. But at least I hope I have done my duty in pointing out to you what the needs of systematic entomology are.—7-23-41.

The Significance of Taxonomy in the General Field of Economic Entomology[1]

E. O. Essig, *University of California, Berkeley*

In order to understand the full significance of the relationships between systematic and economic entomology in this country we must remember that the two were born and nourished as one from the very beginning.

The organization of the State Agricultural Experiment Stations under the Hatch Act of 1887 was responsible for the birth of professional entomology in the United States. It is true that previous to this act there were at least fourteen states which had established institutions for agricultural research and lectures and that a number of these states, including Massachusetts, New York, Illinois, and Missouri, supported investigations in entomology.

There were prior to this date also a number of trained professional scientists teaching entomology. At Harvard College, W. D. Peck gave lectures in entomology as early as 1805 and was followed by W. T. Harris in 1831 and by H. A. Hagen in 1867. A. J. Cook, after completing studies at Harvard with Agassiz and Hagen and receiving a professorship in zoology at Michigan State College in 1867, was certainly one of the first to teach entomology in a college of agriculture, as was also C. H. Fernald at Maine State College in 1872. J. H. Comstock, as an undergraduate student, began lecturing in entomology in the tower room of McGraw Hall, Cornell University, in 1872; and the botanist, C. E. Bessey, taught entomology in the Agricultural College of Iowa in 1876. All of these and a great many of the ablest teachers succeeding them were men of wide training and experience; and, since they were both chief and worker, they were bound neither by tradition nor authority and were a law unto themselves. In those glorious days there were no specialties, no rules of nomenclature, no insecticide formulas—nothing but just plain entomology.

With the possible exception of a half dozen privately endowed and a few state colleges and universities in the United States, entomology in all its varied aspects has been the product of the agricultural colleges and experiment stations and of the Bureau of Entomology of the United States Department of Agriculture. Thus, largely reared under agricultural influences and extensively supported by agricultural funds, even the most extreme of systematists have not failed to realize the importance of a practical approach to taxonomy and nomenclature.

Another point in this relationship of systematic entomology to economic entomology which requires some elucidation is what might be termed the segregation of professional entomologists according to the various kinds of specialization. Thus in systematic entomology there are all the different degrees between those trained in classical taxonomy, morphology, physiology, ecology, laboratory technology, and a combination of all these specialties in those few individuals who still collaborate in the programs of insect control and extermination. Economic entomology has a much more diversified spread and covers a broader scope in the fields of general applied and experimental entomology, agricultural entomology, insect pest control, plant quarantine, toxicology, statistics, and many other related subjects.

Although the general scopes of systematic and of economic entomology overlap, it is important to note that in actual practice they seldom now actually unite and that there is a very distinct gap between them. This "no-man's land" is apparently the result of the passing of the older broadly trained entomologists who were the founders of our national organizations and of the profession of entomology. The few remaining successors of these forebears are the men who are still able to conduct researches in both the systematics and economic problems and the fewer still who have facilities and opportunities to supplement museum taxonomy with biological, ecological, geographical, and statistical investigations under controlled and actual field conditions.

As I look back over the development of entomology during a brief period of thirty

[1] Paper from the Taxonomy Symposium, San Francisco, 1941.

years, it appears to me that this gap has been widening at an alarming pace. Because of the immediate economic implications and the great preponderance of the economic or practical problems, the systematists are being crowded to the wall and the majority of them are wholly excluded from a part in the immediate entomological programs of their institutions and thus have no real opportunities to apply their knowledge and experience in directing and molding the development and trends of entomology in the agricultural institutions of which they are a part. Thus the usefulness of many of the greatest workers in the more specialized and broader fields of entomology and biology is rendered negligible as compared to what might be accomplished by the thorough cooperation of all the possible available resources of entomology as a science.

If it were not for the fact that there are so many of us who are enthusiastically interested and concerned in both the economic and the systematic fields of entomology and who have a like interest in the profession as a whole, we might have grave concern for the future. In spite of the rather discouraging picture often painted for the systematist, we cannot ignore the fact that his dynamic interest in insects has neither lessened nor faltered throughout the years. His meticulous and untiring researches, his publications and collections, his increasingly valuable libraries, and the fundamentality of his accomplishments as an integral part in technical researches and in the teaching curricula of colleges and universities, have increasingly elevated and strengthened the position of entomology among the biological sciences.

Because many of us having applied and commercial interests are now so far removed from the innumerable and perplexing problems of systematic entomology, the significance of taxonomy in the general field of economic entomology may not appear to be an important issue at this convention. It is my contention that at no time can the essential foundational program of any science be neglected if that science is to serve the nation to the fullest degree. Therefore, it will be necessary to discuss the present status, the problems, the facilities, and the future needs of the kind of taxonomy that can best serve entomology as a whole. That kind will also be the most valuable for the applied fields.

If, as an introduction to this symposium, each of you had carefully read the twenty-two chapters of that new and admirable book *The New Systematics*, sponsored by the British Association for the Study of Systematics in Relation to Biology and edited by Julian Huxley, which appeared in 1940, my task would be a very simple one because you would then have a clear insight into the many intricate problems of systematics in the whole field of biology. You would also be cognizant of these facts:

Taxonomy is the focal point and basis for all the biological sciences. Its chief concern is, in the words of Huxley (1940), "with separating and defining species so that the *same name* shall always have, or as nearly as possible, the same meaning when applied to an organism or a group of organisms."

Taxonomy must precede all other forms of biological investigations and furnishes the foundation and frame upon which may be built the results of the researches of all the natural sciences.

Because taxonomy involves practically all biological sciences, it is steadily gaining favor and its value is becoming more fully realized and appreciated by all those in the natural sciences.

An important contribution of taxonomy to biology is nomenclature, or the orderly arrangement of living things into related categories, which often makes it possible to forecast or to determine with considerable accuracy the life history, habits, hosts, and even the control of a new species by referring to known closely related forms. To economic entomology and plant quarantine this is a service of very great importance.

Entomological taxonomy has attempted some gigantic tasks with rather meager facilities and support. Diver (Huxley 1940) has referred to the matter in a very apt manner as follows: "The aim of taxonomy is more than the mere pigeonholing of different organisms on some convenient but completely arbitrary system of card-indexing. It seeks to establish relationships and to determine what degree of dissimilarity is consistent with placing two individuals within the same species. . . . In the vast majority of cases the

taxonomist is compelled to delimit his species from dead material; that is, he must rely solely on morphological characters supplemented by distributional data often of the sketchiest nature. The fields of developmental, physiological, ecological, bionomic, cytogenetic, and biochemical variability are usually closed to him. *The impressive fact is not that taxonomic positions of some rare species are in doubt, nor that in some cases of extreme complexity his assemblages are too small or too large, but that working under such severe limitations he achieves such an extremely close approximation to the facts of nature.*"

In an attempt to meet these new concepts and to become more useful to the applied fields, there *has been* a noticeable development in the correlated fields of systematic entomology as in comparative insect morphology, physiology, ecology, genetics, toxicology, as well as in more intensive and exacting studies in the broader requirements in agricultural and medical entomology, in biological control, in the relations of insect vectors to plant diseases, and in the use of statistical methods, all of which have, in the words of Huxley (1940), "revealed taxonomic facts which inevitably were hidden from museum workers by whom classical taxonomy was built up."

Some of the problems that confront the systematics of the future relate to new concepts in the determination of species. Early entomologists naturally first considered those orders, families, and species of insects that could be readily separated by gross morphological characters and without concerning themselves at all with the possibilities of making laborious microscopic examinations, of studying the exact biology, of conducting breeding tests, and in making genetical, ecological, and statistical analyses.

If we are to accept the modern experimental evidences of species as being self-perpetuating units with definite morphological characteristics either unable to interbreed or, if they do interbreed, producing infertile offspring, and as having geographical, ecological, and genetical distinctness, then the work of the systematist must undergo a complete metamorphosis; he must embark upon an entirely new program.

There are also the very difficult problems of placing in their correct categories the physiological races of insects which involve the so-called resistant strains in agricultural entomology and the biological races met with in biological control work; tasks which the systematist has neither time, space, nor equipment to undertake under present handicaps.

In achieving the new systematics it is not necessary to reject the past. No one would venture to question the great usefulness of the museum worker in the quiet and scientific atmosphere surrounded by his collection of insects and his priceless library. There will always be a place for such as he and it is doubtful if a more suitable environment will ever be found for the solution of most of the problems in taxonomy. The discovery and understanding of such phenomena as mimicry, polymorphism, gynandromorphism, natural selection, intersexuality, seasonal and sexual dimorphism, the phase theory of locusts, and the solution of most of the problems of geographical distribution are largely due to his past accomplishments.

But to attain the new systematics will require a definite, progressive, and emphatic program which should include the following objectives:

1. A definite increase in the technical staffs of entomological museums and a corresponding increase in the appropriations to provide ample and comfortable space and adequate up-to-date facilities for the workers and the collections.

2. Properly equipped laboratories and facilities for the study of living material under natural and controlled conditions.

3. Provisions for the employment of laboratory technicians, secretaries, artists, photographers, and other help to relieve the specialists of as much purely routine work as possible.

4. Opportunities for the systematists to conduct experiments in the field, either alone or in cooperation with geneticists, toxicologists, morphologists, economic entomologists, or other interested parties.

5. Sufficient libraries, collections, and instruments for special studies in particular fields of systematic and economic entomology.

6. Greater facilities for publication. As every entomologist knows, it is becoming increasingly difficult to publish papers of any considerable length, and the very works most needed, such as monographs and catalogs, are almost out of the ques-

tion. (Our own JOURNAL OF ECONOMIC ENTOMOLOGY is able to accept taxonomic papers from systematist members of the American Association of Economic Entomologists only when they involve economic aspects.)

7. Stabilizing nomenclature. All working entomologists would be benefited by any action that would tend to render more permanent those old and well-known scientific names which, under present rules of nomenclature, are constantly being changed for no other reason than to conform to the rules of priority and other purely nomenclatorial matters. Any code of nomenclature soon becomes inoperative unless it can be revised to meet the growing needs of systematics. An essential concern of taxonomy, *i.e.*, the naming of natural objects so that they may be known always and everywhere by *a definite name* is being violated by the present practice of discarding well-known names for meaningless new ones. This is of concern to all of us but more particularly to the economic entomologist and to students and writers in phylogeny, morphology, physiology, embryology, toxicology, ecology, and related subjects. Few of us are able to visualize the far-reaching consequences that radical changes in modern nomenclature have upon the many and varied publications of all of the above-mentioned subjects. Fortunately, until lately, many of the contemplated revisions have been averted by action of the International Committee on Zoological Nomenclature. However, since the present World War has rendered this committee inoperative there is now no higher court of appeal to render decisions concerning the many cases which now await solution. It is my opinion that in the absence of such a directing authority extensive changes involving higher categories should be left in *status quo*.

From the discussion thus far it is evident that the whole field of systematic entomology is already undergoing some significant and drastic changes out of which appear to emerge two rather important lines of future endeavor; *the first*, a greatly expanded classical or museum type of taxonomy and *the second*, an entirely new department which might be called experimental systematic entomology. If professional entomology is to flourish in North America and develop along the lines of the new systematics, then some very radical additional changes must be achieved in general attitude and support by our leaders and administrators as well as in viewpoint, training, and methods of procedure by those entrusted with the teaching and those in charge of the actual work.

Certain of the practical changes have been underway for some years. During a stay in England in 1936–1937 I was greatly taken with the advancements already made in several of the greatest technical institutions in that country. There is a greenhouse connected with the Department of Entomology of the British Museum of Natural History in London in which insects are being reared for study and control. The Imperial College of London has a large and well-equipped experimental station at Slough where there are excellent facilities for experimental investigations in all of the biological sciences, including systematic and applied entomology, and where systematists and economic men spend their summers doing experimental and practical research work. Cambridge University, than which there is no greater classical and scientific institution of higher learning, has recently established a modern Entomological Field Station comprising a well equipped general laboratory, private research rooms, differentially heated insect rearing houses, a large unheated insectary, an insect-proof screen house, and accessory buildings located on two acres of experimental ground, including permanent plantings of shrubs and trees and such other insect host plants as might be desired for special investigations. This station affords excellent and adequate opportunities for the study of insects under natural and artificially controlled conditions and approaches an ideal set-up for all research workers in systematic, experimental, and applied entomology.

In the United States many institutions are equipped with greenhouses, insectaries, and laboratories for special research problems for workers in economic or applied entomology; but few of those administering these *sancta sanctora* appear to have grasped the importance of either admitting the systematists into their sanctuaries or of furnishing similar adequate facilities for experimental work along purely taxonomic and biological lines.

In the agriculture colleges, agricultural experiment stations, the U. S. Bureau of Entomology and Plant Quarantine, and a number of privately endowed institutions, facilities are available for supplying most of the immediate needs of experimental systematic entomology as heretofore enumerated. I believe, too, that in nearly all cases the economic entomologists will welcome the services and cooperation of specially chosen taxonomists in connection with many of the problems under investigation at the field laboratories and stations. In the determination of specimens and researches along the lines of morphology, physiology, ecology, geographical distribution, and in certain types of laboratory technique, the systematist would materially aid in the solution of many perplexing problems and, in turn, he would have opportunities to develop a broader and more practical viewpoint and means for experimental investigations that would contribute substantially to the interests of both taxonomy and applied entomology.

I wish to make the emphatic claim that the present dire situation regarding systematic entomology is no fault of the entomologists of this country; that the taxonomic and economic workers have always cooperated in as complete harmony as can be expected of any group of individuals operating under such diverse conditions; that the close affiliation of all entomologists in these two great national organizations and the cordial harmony between the officials and members alike are sufficient reasons for believing that even closer cooperation may prevail in the future.

To insure the success of such radical changes as are desirable it will be necessary for the administrative officials first to grasp the importance and the needs of modern entomology and to fully understand the real values to be gained through closer relationships between the various branches of entomology and the other biological sciences and then to provide the necessary facilities for their development according to modern scientific lines, as is so well expressed in the new systematics.

In concluding I trust that this symposium will convey to each of you the importance of fundamental and sound work in all fields of entomology, that it is desirable and urgently necessary to secure closer relationships between systematic and economic research, and, most of all, that the objectives which we have failed to achieve as individuals may be acquired by an intelligent and united effort on the part of all of us as members of these two great national organizations of entomologists.1-6-42.

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THE NEW YORK MEETINGS

The EASTERN BRANCH of the Association will hold its annual meetings in New York on November 19 and 20. Headquarters will be in the Hotel New Yorker. All entomologists are invited to attend.

The AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS and the ENTOMOLOGICAL SOCIETY OF AMERICA will hold their annual meetings in New York on December 29, 30 and 31. Joint sessions of the two organizations will occupy a part of the first day and the Entomologists' Dinner will be held on the evening of December 30.

Headquarters for both groups will be in the Hotel New Yorker.

The Relation of Taxonomy to Biological Control[1]

C. P. Clausen, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The preceding speakers have called attention to the importance of taxonomy in relation to entomological research in general and to several fields of applied entomology. It remains for me to discuss its relationship to biological control. Investigators on biology and chemical control are concerned, in their experimental work, with a single insect and their difficulties do not pertain to that insect but result from attempts to correlate data reported by workers in other regions and countries with their own. Discrepancies in results become understandable only when the separate identities of the insects dealt with are eventually determined.

In contrast to this, what is the picture with respect to biological control? This type of control, in general, is applied against insect pests of foreign origin, and the natural enemies utilized in their control are likewise obtained from abroad. Thus we have for consideration a complex consisting of the host insect in this country, the host insect in other parts of the world, the series of natural enemies occurring in the countries of origin, and, finally, the several pest insects that may serve as alternate hosts of these natural enemies. Instead of being concerned with the identity of only a single insect we are confronted with a series of possibly several dozen species, and a mistake in the identity of the host may result in the complete loss of years of work and the useless expenditure of large amounts of money. If, for instance, a pest is of oriental origin but is mistakenly identified as a closely related European species, the search for natural enemies in Europe, and their collection, rearing, and colonization for biological control, might well prove utterly futile. The identity of the parasites themselves is not of so great importance as long as it is known that they are directly associated with the properly determined host. The alternate hosts assume a position of importance mainly when the relationship is obligatory and the existence of a specific insect in the new environment is essential to the perpetuation of the parasites that are being imported.

[1] Paper from the Taxonomy Symposium, San Francisco, 1941.

The field biologist is often impatient with the taxonomists and unduly critical of their mistakes, this being due, to a considerable extent, to a lack of appreciation of the difficulties that confront them. That they should occasionally make incorrect determinations is understandable, especially if the pest insect is of foreign origin, and the specimens they have for examination are from domestic sources. The type specimens of such pests are usually in foreign collections, homotypes may not be available in any local collection, and the original descriptions too often are so meager as to be of little aid. It is often true that these immigrant pests are uncommon and of little importance in the countries of origin and, as a result, the taxonomists may not have detailed information on food habits, etc., to aid them in arriving at a true determination. These same difficulties confront them in the determination of parasite species, a great many of which have not been previously associated with their hosts.

Pemberton (1941) cites an outstanding instance of the value of insect collections, assembled for taxonomic study, in the solution of a biological control problem. Some 20 years ago the fern weevil, *Syagrius fulvitarsis* Pasc., became very destructive to Sadleria ferns in a forest reserve on the island of Hawaii, and control measures became necessary. Entomological literature failed to reveal its occurrence anywhere outside Hawaii except in greenhouses in Australia and Ireland. These records, of course, gave no clue as to the country of origin. However, while engaged on other problems in Australia in 1921 Pemberton had the opportunity of examining an old private insect collection at Sydney, and among the beetle specimens was a single *Syagrius fulvitarsis* bearing the date of collection, 1857, and the name of the locality in Australia from which it was obtained. This provided the key to the solution of the problem, for a search of the forest areas indicated on the label revealed a small population of the beetles and, better still, a braconid parasite attacking the larvae. Collections were made immediately for shipment to Hawaii, and

the establishment of the parasite was quickly followed by satisfactory control of the pest. The data borne on a label attached to a single insect specimen in 1857, in Australia, thus contributed directly to the successful biological control of the pest in Hawaii 65 years later.

The stimulus that led to development of the project for the biological control of the citrus black fly, *Aleurocanthus woglumi* Ashby, in Cuba, other West Indian Islands, and Central America, and which resulted in complete success, was provided by the discovery of several of its parasites in tropical Asia by Silvestri in 1925, while he was engaged upon other problems. It is improbable that this control project would have been undertaken had not Silvestri's information been available.

The history of the attempts to bring about the biological control of the red scale, *Aonidiella aurantii* (Mask.), and, to a lesser extent, the yellow scale, *A. citrina* (Coq.), in California covers a period of about 50 years. The two species are usually distinguished on citrus in the field in California by color and because of a difference in the parts of the plant which they infest. Upon other plants and in other parts of the world, however, these differences do not occur or at least are much less distinct. It was not until 1937 that reliable morphological characters were found that permitted positive determination of the adult scales.

Meanwhile, the attempt to control the California red scale by the biological method had been going on and a promising oriental parasite, *Comperiella bifasciata* How., was imported into California from southern China in 1905, and periodically thereafter from several Asiatic countries. It was believed at the time that the imported material was from *Aonidiella aurantii*, yet the parasite failed to reproduce upon that host in California. In the course of the studies in California, *Comperiella* from Japan was colonized upon the yellow scale and, surprisingly, became established. Detailed biological studies revealed that the eggs of *C. bifasciata* from Japan were encysted and destroyed very soon after deposition when placed in the body of the *A. aurantii*, whereas they developed normally in *A. citrina*. When the characters distinguishing the two scale insects became known, an examination of the Japanese scale material revealed that it was *Aonidiella taxus* Leon. rather than *A. aurantii*.

This discovery did not complete the story, however, as the red scale problem remained unsolved. A study of Compere's collection by the California Citrus Experiment Station has recently determined that some of the *Aonidiella* on citrus in the Hong Kong section parasitized by *Comperiella* is actually *aurantii*, and that it is there heavily parasitized by what is evidently a physiological race of *Comperiella bifasciata*. Stocks of this race are now being reared on the red scale and colonized in California and the outcome of this introduction is awaited with much interest.

In summing up the situation as it is now understood, the two very closely related species of *Aonidiella* that infest citrus are each attacked by a physiological race of *Comperiella bifasciata*. Although it cannot develop in *A. aurantii* the yellow scale race of *bifasciata* reproduces readily upon several armored scales of other genera. The two so-called races are inseparable morphologically on the basis of the characters now known, but the differences in habit that have been discovered lead one to suspect that characters may eventually be found that will establish them as distinct species. In an address before the Pacific Science Congress, in 1939, Compere concludes his discussion as follows: "An unpublished history of the attempt to control the red scale biologically has attained book-size proportions, and it is largely an account of a series of contradictions and blunders, all directly due to the failure of taxonomists, biologists, and collectors to identify correctly the insects with which they were working."

The mealybugs of the genus *Pseudococcus* comprise a group of important plant pests against which the biological method of control has been especially successful. This work, however, has been handicapped and control delayed because of difficulties in determining the exact identity of the forms occurring in different countries. The first species against which such efforts were directed was *P. citri* Risso, a pest of citrus in the Mediterranean region and California and common in greenhouses throughout the world. The mealybug infesting coffee in Uganda and other tropical countries, *P. kenyae* Le P.,

was long believed to be this species, as was that on citrus in Palestine. This complex is now being gradually broken up into its component species, but the earlier confusion resulted in large expenditures of time and money in the importation of natural enemies into California, Uganda, and elsewhere that, as is now known, were useless upon the particular forms occurring in those regions.

Another *Pseudococcus* complex that has attracted much attention in recent years centers about *P. comstocki* Kuw., a pest of pear native to Japan. In that country there is also a very closely related form that attacks citrus. Some years ago an outbreak of mealybugs occurred upon apple in the eastern part of the United States and the species involved was identified as *P. comstocki*. The very destructive infestations upon citrus in Palestine about the same time were believed to be of the same species. The most recent opinion by taxonomists is that the two forms in Japan are distinct species and that the American infestation is of the true *comstocki*, whereas that in Palestine is of the form attacking citrus in Japan. Not only that, but it now appears that both forms occur in other parts of the world also, and in some instances are known under other names. The uncertainty regarding the identity of the different members of the *comstocki* complex would have resulted in much misdirected effort in the several projects for biological control were it not for the fortunate circumstance that the more important parasite species occurring in Japan attack both mealybug species with equal facility.

A third instance in the mealybug group is represented by *Pseudococcus nipae* (Mask.) and *P. pseudonipae* (Ckll.). These were originally described as distinct species but were later combined as one, in spite of noticeable color differences. In Hawaii *P. nipae* is fully controlled by *Pseudaphycus utilis* Timb., which, when tested in California, proved to be unable to develop in *P. pseudonipae*. As a result of this discovery the two mealybug forms were reexamined and their separate identities established.

One of the best known instances of confusion in the identification of insect parasites is found in the genus *Trichogramma*. The common forms occurring in Europe and North America are indistinguishable morphologically in any stage, and it is customary to separate them on the basis of their habitats and by their developmental responses to experimental conditions. The uncertainties and doubts that have arisen as a result of this condition have clouded much of the work that has been done in testing the value of these parasites in the biological control of a series of pests. While all species or races are able to develop in the eggs of a very wide range of hosts, and reproduce equally well in the insectary upon those of the Angoumois grain moth, yet it is believed by many that the stocks used in the field tests have been mixed or were of a form unsuited to the particular environment in which they were released. The bulk of the literature upon the biology of species of this genus in North America and Europe, and upon their utilization in biological control, is useless because it is impossible to know the particular species which the different investigators were using. These difficulties would disappear if it were possible to distinguish the adults of the different forms by morphological characters.

The work on the biological control of the black scale of citrus, *Saissetia oleae* (Bern.), by the California Citrus Experiment Station is a conspicuous example of the interdependence of the biologists and taxonomists. During the 50 years since study of this problem began approximately 70 species of Chalcidoidea have been reared from this single host in different parts of the world. Among them are 22 species of the aphelinid genus *Coccophagus*. The recent spectacular discoveries by S. E. Flanders (1937) of sex differentiation in host relationships of the immature stages in some species of the genus have provided the knowledge essential for their successful propagation and colonization. This work was closely tied in with the concurrent taxonomic studies on the genus by H. Compere. Here we have the ideal situation of biologist and taxonomist working together on the solution of a single problem. The advances that have been made are unquestionably greater than would have been possible had they been working independently.

Among the parasitic insects that are widely employed in biological control perhaps the greatest difficulty in obtaining accurate determinations exists in the

family Tachinidae. The adults of many species of this family are very similar morphologically but have distinctive habits and host preferences. A large proportion of the tachinid parasites of the gypsy and brown-tail moths imported into the United States were misidentified during the early phases of the project, and for many years *Carcelia separata* Rond., from the brown-tail moth, and *C. gnava* Meig., from the satin moth, were considered to be identical and importations and releases were made accordingly. A similar confusion existed in regard to the identity of the tachinid parasites of the European corn borer imported from Japan and the Orient, and among the species of *Theresia* that have been imported from different parts of South America in the attempt to control the sugarcane moth borer.

The well known *Exorista larvarum* (L)., formerly included in the genus *Tachina*, a parasite of the gypsy moth and many other Lepidoptera in Europe, was imported in large numbers and colonized upon the gypsy moth in New England. In this country there exists a native species, *E. mella* (Wlk.), which until very recently was indistinguishable on the basis of adult characters from *E. larvarum*. It differs in habit, however, as it seldom attacks the gypsy moth and, furthermore, its larvae consistently pupate within the remains of the host, whereas those of *E. larvarum* emerge from the host caterpillars for pupation. The inability to distinguish between the adults of the two forms led to the belief that they represented varieties or races of a single species and that interbreeding after release in the field would probably eliminate the preference of the European form for the gypsy moth. These considerations led to the removal of *E. larvarum*, in 1912, from the list of European parasites of the gypsy moth considered to be promising in the biological control of that pest and the brown-tail moth in New England. This decision was later reconsidered and the large-scale importations from 1925 onwards resulted in establishment. Studies by W. F. Sellers during the past year have revealed that the larval instars also possess morphological characters by which the two species can be distinguished.

The biological control work upon the European corn borer in the United States resulted in the importation of a number of species of Tachinidae, among them *Zenillia mitis* Meig and *Z. roseanae* B. & B., from southern Europe. These were colonized rather extensively, some 174,180 adults of the latter species having been released in the infested area. Some years after the completion of the colonization program it was concluded by the taxonomists that *Z. mitis* is identical with the native *Z. caesar* Ald., and *Z. roseanae* with the native *Phorocera erecta* Coq. If this is correct, a large amount of effort and money was fruitlessly expended that could have been saved by proper determinations at the time the first importations were made. If incorrect, as now seems to be probable from more recent studies, much time has been lost in making recovery collections to determine establishment and distribution.

W. R. Thompson (1922) was the first to point out the existence of distinct morphological differences in the immature stages, especially the first-instar larvae, of species of Tachinidae that are very similar or cannot be distinguished in the adult stage. The existence of such differences should be an aid in identification, and warrant the belief that study of the adults will eventually reveal specific differences in that stage also. These instances are analogous to the red and yellow scale problem, where more than 60 years of study finally culminated in recognition of the character separating the two species.

In his recent *Manual of Myiology*, Townsend accompanies his descriptions of species of Diptera with information on the reproductive systems of the females as well as on the eggs and first-instar larvae. Such information is invaluable, not only to the taxonomist in his effort to identify his specimens correctly, but to the biologist as well. The biologist should bear in mind, however, that certain of this information, with respect to the species that he submits for identification, is not directly accessible to the average taxonomist, and the biologist has the opportunity and responsibility of contributing material and information that will lead to correct identification. It is not enough, either in the Tachinidae or in any other group, that he submits a few specimens of adults, but instead the series should be sufficiently large, and the specimens in good condition, so that variations may be studied. With the adult specimens

he should submit, whenever possible, specimens of the immature stages and as full notes as possible relating to host preferences and habits. Such cooperation between the field biologist and the taxonomist is of even greater importance in the identification of parasitic insects than others because of the complexity that exists in the relationship between host and parasite and the modifications in form and habit that have arisen because of that relationship.

The examples which have already been given illustrate the importance of exact knowledge of the taxonomic position of the parasites that it is proposed to utilize in biological control, yet it needs to be emphasized that such knowledge cannot be accepted as a substitute for detailed biological studies of each species, but instead should serve only as a guide in such studies. Determination of a species as belonging to the genus *Tetrastichus*, for example, provides no clue as to its host preferences or relationships, but it does point to the need for careful biological study before release, as species of that genus may be either primary or hyperparasitic in habit.

We have one outstanding example of the harm that follows blind reliance upon the supposed conformity of a species to the general habits of the group to which it belongs. From the black scale material imported into California from Australia in 1900 and 1901 there emerged a considerable number of adults of an encyrtid, *Quaylea whittieri* (Gir.). There apparently was some doubt regarding the status of this species, even at the time it was forwarded, and specimens were consequently submitted to taxonomists for determination. The reply pointed out that the species belonged to a group that, on the basis of knowledge of that time, was consistently primary in habit, and for this reason it could be safely released. This opinion was accepted as final and, without any actual tests with the parasite itself, the stock of adults was released and the parasite quickly became established and generally distributed. While it developed at the expense of several black scale parasites than present in California, yet its harmful potentialities were not fully realized until nearly 25 years later, when it increased to such an extent as largely to nullify the effectiveness of *Metaphycus lounsburyi* (How.), a very promising species introduced from Australia in 1918. According to Smith & Compere (1928), *Quaylea whittieri* may even prevent for all time the control of the black scale by the biological method.

It might perhaps be proper to point out at this time the taxonomic work on insect parasites and their hosts that has been stimulated by biological control activities. The outstanding example in this line is the study made upon the sugarcane leafhopper, *Perkinsiella saccharicida* Kirk., and its natural enemies in the course of the attempt to control that pest by the biological method in Hawaii. This involved not only a detailed taxonomic study of the Cicadellidae themselves but of the different families of parasitic and predaceous insects that attack leafhoppers. Many studies on various groups of the Tachinidae have been undertaken as a direct result of needs brought out in biological control work on many lepidopterous pests. The researches upon the genus *Coccophagus* have already been referred to, and more recently detailed studies of the genera *Exenterus* and *Allotropa* have been undertaken because of needs developed in the course of biological control work.—1-19-42.

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The Significance of Economic Entomology in the Field of Insect Taxonomy[1]

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It has been customary in academic and professional fields of entomology, when attempting to evaluate taxonomic studies of insects, to appraise taxonomy on the basis of its significance to economic entomology or economic biology. This attitude has been ably presented by the first speaker on this symposium, and I have no hesitancy in stating that all competent entomologists are in accord with his thesis. Three other speakers on this program furthermore have given us an excellent and definite visualization of the character and numerous fundamental problems now challenging our best research efforts in selected fields of applied entomology. The reverse attitude, that economic entomology is of significance to insect taxonomy, has been subject to little inquiry, notwithstanding obvious realities.

There is no need before entomological societies such as assembled here for me to present a documentary or lengthy statement of the pattern followed in the development of the intricate and varied fields of entomological activities as they now exist, particularly in the United States and Canada. It will suffice, I am sure, and do justice to the facts to state tersely that modern applied entomology has its origin deeply rooted in the natural history and taxonomical studies of past years. Once born and established on a sound basis, applied entomology, for readily understandable economic reasons, has grown to such proportions that it is a veritable giant among scientific enterprises in the field of biology. Fortunately, this giant of modern applied entomology is not all bulk, in the manner of great reptilians of long past geologic periods. In the thinking, planning and procedures of this giant there is intelligent realization of the values possessed by its parents, one of which we may properly designate as taxonomy.

Since the thesis of this paper is an attempt to establish the significance of economic entomology to insect taxonomy, it seems advisable before proceeding further that I present my concepts of the character of these two fields of entomological activity. My use in this paper of the phrase "economic entomology" is the usual one of today, in that it involves a broad concept including all kinds of insect control, coupled with general biological and ecological investigations. I think you will have no quarrel with this usage. That economic entomology during the last 30 years has been almost completely revolutionized in point of view and methods is an old story, and requires no further amplification here.

That revolutionary changes comparable in magnitude to those in economic entomology are now taking place in insect taxonomy is less widely recognized. The remodeling of taxonomy now under way consists of new methods of approach to problems and an eagerness to utilize factual material from every field of science. Taxonomy is now feeling the impact of the development and advances in genetics, cytology, ecology, physiology, general economic biology and other fields of modern scientific studies. That taxonomy is now drawing upon all fields of scientific investigation is quite evident from even a most cursory examination of the literature of recent years. There is a wide gulf in methods of approach between the *Systema Naturae* of Linnaeus of 1758 and such papers as Cushing and Patton (1933) on screwworm flies, Goldschmidt's (1932) studies of geographical variation, Hackett and Missiroli (1935) on mosquitoes in Europe, McKenzie (1937) on differences in California red and yellow scales, and many other studies which might be cited. The basic definition, however, of insect taxonony as the classifying and arranging of species and groups of species into systems which exhibit relationships still stands, as does the basic definition of applied entomology. If your concept of insect taxonomy has not been brought up to date, along with your concept of applied entomology, I suggest a perusal of a rather recent and stimulating book with the title of *The New Systematics*, edited by Julian Huxley.

Now, just how is economic entomology

[1] Paper from the Taxonomy Symposium San Francisco, 1941.

significant to insect taxonomy? Some time ago, in order to get a better appraisal of this situation than my own limited experience had to offer, I wrote to a number of entomologists and requested their ideas in regard to this subject. The replies were very enlightening and I am sorry that limitations of time will not permit individual acknowledgment of them or quotations from some of the most informative. I find that economic entomology is significant to insect taxonomy in many ways and that these ways can be grouped conveniently under three major categories.

Because of the character of its problems and the funds at its disposal, economic entomology, and economic biology in general, has developed a wealth of equipment and techniques for the rearing and studying of insects. A high percentage of new articles, whether they deal with biological control, chemical control, general biological and ecological studies, or some other phase of economic entomology, make contributions to the subject of new equipment and techniques for the rearing and studying of insects. Equipment and techniques have become so indispensable that we now have available such books as the *Culture Methods for Invertebrate Animals*, prepared by a group of American zoologists, and a *Manual of Entomological Equipment and Methods* in two parts by Alvah Peterson, together with numerous leaflets and shorter articles dealing with this subject. Although it would be incorrect to say that taxonomists were not interested in such techniques and equipment and did not contribute to their development, I believe it can be stated with safety that economic entomology has supplied the chief and greatest impetus for such work.

Earlier I have pointed out that taxonomy is now feeling the impact of investigations in all other fields of science. The modern taxonomist is often responsible for diagnostic work which determines when and when not to spray, to quarantine, to change our cultural programs, which puts in motion other programs necessitating intricate ecological and biological studies requiring large expenditures of money, as well as involving safety of life and preservation of varied resources which are essential to our well being.

The day of the ready differentiation of the insect fauna, based upon easily found conspicuous morphological differences and once sufficient to meet exhibitional and other needs, is very rapidly going the route of the dodo. The modern taxonomist needs to study large series of population units, and the more that he knows about all phases of their habits, biology, internal and external morphology, immature stages, races, etc., the sounder and more useful will be his taxonomic conclusions. Economic entomology, by making available to insect taxonomy the advanced methods and techniques which it has developed, and which, for obvious limitations, it is doubtful if insect taxonomy would ever originate, has already greatly benefited insect taxonomy. This contribution will be even more significant in years to come.

Another manner in which economic entomology is proving significant to insect taxonomy is by giving objectiveness and revealing the strength or weakness of taxonomic studies which through necessity are first based upon the more observable morphological likenesses and differences. All parts of the country and all phases of economic entomology can offer examples in support of this contention. Almost every reply received in answer to my letter, mentioned previously, pointed out one or more examples of this effect of economic entomology upon taxonomic studies.

This contribution of economic entomology in giving objectiveness to taxonomic studies and of putting the spotlight on problems in need of restudy is so important that the citation of a few selected examples is warranted. Medical entomology is replete with classic examples of increased and better taxonomic investigations as a result of the advances and discoveries made in our knowledge of the important role of insects and related groups in the transmission of organisms pathogenic to man. Prior to the discovery that mosquitoes carried malaria, these insects received much less attention than certain showy and conspicuous groups of beetles, moths and butterflies of minor or little economic importance. After the great demonstrations of the role of mosquitoes as vectors of diseases, the taxonomic study of these insects took a tremendous spurt and the result has been a series of notable publications. These studies of mosquitoes have now proceeded

so far that every stage and reaction of these insects is subject to close scrutiny, and races are recognized on the basis of egg structure, habits and zoo-geographical distribution.

The screwworm fly situation of some years ago gives us another instance of the manner in which economic entomology stimulates taxonomic studies of a higher order, of greater exactitude and of more useful character. Rearing and field studies of screwworm flies in connection with economic investigations led finally to the recognition of *Cochliomyia americana* Cushing & Patton as distinct from *Cochliomyia macellaria* (Fabricius) and in turn radically changed concepts in control measures. Numerous other examples involving fleas, ticks and other insects in the general sphere of medical entomology could be cited.

In the field of chemical control numerous examples exist where such studies have been the stimuli or the necessity for new taxonomic investigations of certain species, genera or other groups. Let us take the quite recent case, here in California, of the red and yellow scales on citrus fruits. Although another speaker participating in this symposium has mentioned the case of the red and yellow scales in support of the thesis that fundamental taxonomic studies are a necessity of applied entomology, this instance also is an illustration that applied entomology is a great, significant or directional factor in taxonomic studies.

Economic studies of forest insects have played a major role in shaping the growth of taxonomic work in the United States and Canada. The field studies of such workers as Hopkins in the United States and Swain in Canada have been basic to a taxonomic understanding of the Scolytidae. Special need for recognition of the immature stages of forest insects has led to a series of splendid papers in this field by a large number of workers, and profound changes in the accepted classification of numerous groups of insects.

This year there have appeared publications by two Canadian workers, Stanley G. Smith and W. A. Reeks, regarding sawflies causing severe defoliation of spruce in Canada. As a result of the work in Canada and Europe, it now seems certain that two species are present in Europe which take the names of *Diprion polytomum* Hartig and *Diprion hercyniae* Hartig, and are not synonymous as considered by Europeans since Hartig. *D. polytomum* has a basic chromosome number of six, practically no tendency to diapause, and facultative parthenogenesis; this species has not yet been discovered in North America. *D. hercyniae* has a basic chromosome number of seven, a marked tendency to diapause which may last as long as six years, and obligatory parthenogenesis; this is the species which is present in North America, being distributed in Ontario, Quebec and the maritime provinces of Canada and throughout the New England section of the United States. I give this rather complete statement regarding the spruce sawfly because it illustrates admirably what I mean by the fact that economic entomology and the results of many other fields of research are more and more going to make significant contributions to taxonomy. The necessary time, expense and effort to carry on these penetrating and extensive investigations in two continents would undoubtedly never have been contributed, at least not for many years, if it had not been for the viewpoint and needs of economic entomology.

The speaker just preceding me, Dr. C. P. Clausen, has given us numerous examples of how biological control leans heavily upon taxonomic research, and without such studies this important phase of insect control work would be severely handicapped. Here again I can point out that all of this control work is of great significance to taxonomy because it supplies taxonomists with series of specimens, many of which are reared in large numbers, furnishes a great amount of associated biological data, and directly necessitates taxonomic work because of demonstrated and pressing needs.

I might go on and on along this line of thought with examples from all fields of economic entomology and representative of all sections of North America, but I believe this is not necessary to establish my argument. The examples given are typical and fully demonstrate that economic entomology is significant to insect taxonomy in pointing out its strength and weaknesses and in focusing attention upon special studies which are highly desirable.

The last argument I wish to advance is the most obvious of all, and requires the least explanation; namely, that economic

entomology, at the present time, is the meal ticket for insect taxonomy because, directly or indirectly, it provides funds to employ personnel and to carry on such studies. Funds appropriated for economic studies by the U. S. Bureau of Entomology and Plant Quarantine are frequently and justifiably allocated to taxonomic projects. A good example of this is the taxonomic studies of fruit flies made several years ago as a result of the Mediterranean fruit fly problem in Florida.

A large number of workers in the United States and Canadian entomological services scattered over the continent, although primarily engaged in economic investigations, devote a considerable amount of time to taxonomic studies closely correlated with biological studies. Then, too, we have within the federal entomological agencies of this and other countries such administrative units as the Division of Insect Identification of the U. S. Bureau of Entomology and Plant Quarantine, units maintained and sponsored because of the taxonomic needs of economic entomology.

Within the states there is some counterpart of the federal organization. However, few states give direct employment to taxonomists with funds for economic investigations, and most of the taxonomic work which goes on is done indirectly by entomologists working primarily on economic projects, or by entomologists employed in connection with the teaching of entomology. Among exceptions to this general condition within the states, I may mention the Illinois Natural History Survey which directly employs taxonomists as such, and maintains a Section of Insect Survey which is taxonomic in objectiveness but so organized that it can carry on its own biological or ecological investigations and field work to supplement morphological studies. It must be admitted, of course, that the Survey justifies this work on an economic basis. That basis in Illinois involves aquatic biology, game management, forestry and applied botany, in addition to economic entomology, because of the broad character of the Survey investigations in all renewable natural resources fields.

I shall make no attempt to appraise the actual amount of funds appropriated for economic studies which are directly or indirectly used for taxonomic studies. It will suffice to state that the amount involved is considerable and amply justified.

In closing, I wish to make it clear that what I have said about the needs and requirements of modern taxonomy is no disparagement of the efforts of earlier workers. They have played their part on the taxonomic stage in accordance with the needs of the time and the tools at their disposal, and have provided as a whole a fundamental basis for the initiation of future more comprehensive studies. Some of this past work has been excellent, some good and some poor, and the same applies equally well to economic entomology. However, in this latter field of work the printed record is less easy to read, and the poor work can be more quickly forgotten.

The taxonomy of the future must draw heavily upon the geneticist, the cytologist, the biometrician, the ecologist, the physiologist, the economic entomologist, and workers in many other fields of science. It seems certain, too, that the economic entomology of the future will lean even more heavily than now upon the diagnostic work of the taxonomist and the systematic schemes he devises.

Taxonomy, of itself, is not spectacular, and has little appeal in legislative halls or budgetary hearings. Economic entomology has a real and serious responsibility from the standpoint of its own selfish needs in guaranteeing that its reciprocal partner, taxonomy, has the opportunity and funds to function as it should. The present well-trained, full-time force of taxonomic workers in this country and elsewhere is not sufficient to meet the present needs of ecological, biological and applied entomological investigations of a broad and varied character. Officials in responsible federal and state administrative positions must insist that funds and personnel for more comprehensive taxonomic studies be secured; otherwise, the important aspects of the significance of economic entomology to taxonomy will not have the optimum and desired effect. —1-26-42.

Fundamental Taxonomic Problems in Quarantine and Nursery Inspection[1]

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The topic assigned to me in this symposium would seem to imply the existence of certain taxonomic principles that are of greater significance in quarantine and nursery inspection than in other branches of applied entomology. However, the really basic principles of taxonomy, which are accuracy of identification and recognition of relationships between different organisms, concern all parts of the field. If they apply with particular force in quarantine and nursery inspection it is simply because there is more taxonomy in those activities than in some others. The prime function of the inspection service is to control the distribution of injurious insects, and obviously the first step in that effort must be identification of the forms encountered. A large number of independent decisions may need to be made every day at a single inspection station, and each of these decisions involves insect identity. Taxonomic questions, therefore, constitute a large and important part of the problems in this field; and I think it may be said that the principles that are fundamental in taxonomy are at the same time guides to sound regulatory procedure.

When Linnaeus and a few other naturalists were giving the first real impetus to the study of insects, less than two hundred years ago, very few distinct species were recognized. Gradually, however, more and more new insects were discovered, and many of those which had been considered known were found actually to be composites of a number of quite different things. Consequently, there has been a steady increase in the forms that have been described and named, and now it has become evident that the number of different kinds in existence is almost without limit.

It is this overwhelming abundance of kinds that has created the need for a special body of workers to supply promptly the information on specific identity essential to the proper conduct of insect regulation. As the field has broadened there has been a corresponding, consistent development of specialization in taxonomy until now even each of the major orders is considered too large and complex to enable a single worker to meet the increasingly exacting needs for identifications in any one of them. For instance, the Division of Insect Identification of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, has on its staff three dipterists, five hymenopterists, four lepidopterists, seven coleopterists, and so on, each specialist dealing with a limited section of his respective order. Yet, even with that degree of specialization, only about two-thirds of the identifications made by the group as a whole during the past year were definite and complete. The remainder were qualified or represented merely generic or family placement. Some of the samples received were too meager or in too poor condition for identification. Assistance required for proper preparation of all specimens was not available, and there was not sufficient time for thorough study of all the material and for exploration of the pertinent literature in every case. Very largely, however, failure to supply complete and unqualified identifications for nearly one-third of the items received reflects the inadequacy of our knowledge, and the growing caution on the part of the taxonomist that has resulted from a recognition of the need of critical revisionary studies as guides to sound identification.

Obviously, there should be some concrete representation of each species or other elementary segregate to serve as a universally accepted basis for identification. Accordingly, when a taxonomist describes a new insect he designates one specimen as the holotype, which is, technically, the final court of appeal in determining the particular unit to which a given name applies. Around this, however, there needs to be built the species concept, the proper formulation of which will permit the recognition in any stage of development, of individuals which belong to that species. Adequate descriptions,

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availability of type specimens, and abundant material with associated biological and distributional data are essential to the development of such concepts. In no connection are these conditions more essential, and at the same time more imperfectly met, than in the identification of quarantine interceptions. Such material may come from any part of the world, including regions of which the insect fauna is relatively very poorly known; and much of it consists of specimens that are immature.

It may also include forms which represent significant biological segregates, but which are not yet distinguishable on structural characters. All of you who attended the Philadelphia meetings last year, and others of you, too, who have read the published paper, recall Professor Harry Smith's (1941) splendid analysis of problems in applied entomology created by racial segregation in insect populations. One of these which right now is troublesome to quarantine officials of California concerns certain cherry fruitflies of the genus *Rhagoletis*. It involves the possible identity of the form on cultivated cherries in Oregon with that which attacks wild cherries in the Sierra Nevada region of California. Thus far, specialists on Diptera have been unable to answer this question positively.

A great many species, as currently identified, are not the clear-cut entities which the literature seems to call for, and which the harried taxonomist fervently wishes did exist. Instead they often comprise numerous more or less distinct populations some of which are sufficiently well marked to be recognized as subspecies or even species, whereas others are less clearly isolated from the mean population although in behavior, or even in the general appearance of long series of specimens, they may be distinguishable. Accordingly, many so-called species are heterogeneous, being made up of smaller units of variable distinctness, and the question of precisely where to draw specific lines becomes most difficult to answer.

Every major subdivision of the insects contains numerous subordinate groups within which identifications can be regarded as only tentative, or can be made only for one sex, form, or stage, until suitable material and the required study enable the establishment of correct and complete concepts for the elementary units which comprise those groups. How inaccurate our identifications may be is not apparent without such study. Probably 40 or 50 different species of leafhoppers belonging to the genus *Empoasca* were identified as *fabae* (Harr.), the potato leafhopper, until work by DeLong and others clarified the situation. The raspberry fruitworms, both in the eastern states and on the Pacific Coast, are generally known as *Byturus unicolor* Say, but in Barber's critical review of these beetles, which is now in press, he shows that several species have been confused under this name and that the economic forms are distinct from *unicolor;* furthermore, that the eastern and western populations are not the same. Various species of the weevil genus *Conotrachelus* have been recognized as important pests in South America, where the group has seemed to be unusually well represented; but, even to coleopterists, Fiedler's (1940) recent monographic work on this genus was something of a shock. He treated approximately 600 species of South American *Conotrachelus*, of which 416 were described as new. Recent unpublished studies by Buchanan indicate the existence of an amazing complex of very similar but distinct forms in the South American group of so-called white-fringed beetles comprising the subgenus *Graphognathus* of the genus *Pantomorus*. When first discovered in the Gulf Coast states in 1936 only one species was thought to occur there. Buchanan's work, however, has shown that there are actually several closely related species in that area.

Numerous similar illustrations might be given; but it must be acknowledged that, although they have added importantly to the sum total of our knowledge of the groups involved, the results of such studies are seldom final and complete. In the fruitflies of the genus *Anastrepha* the investigation of ovipositor characters has resulted in conclusions concerning specific limits that are undoubtedly more accurate than those derived earlier from characters of the wing pattern. They are, however, applicable only to one sex, and we must admit that we still lack a reliable classification of the males. On the other hand, in numerous groups, studies of the male genitalia have produced sounder specific concepts than

those previously held, but the identification of the females may be difficult or as yet even impossible. Again and again samples of Tetranychidae, or spider mites, consisting entirely of females, are received for identification. Sometimes the collector considers the smaller males to be immature specimens and, on this account, does not take them, but often populations found late in the season or during the winter contain no males. In any case such samples are usually not spcifically identifiable since the essential characters used in determination are those of the male sex and satisfactory distinctions between the females are not yet known. To go a step further, we find that in the ants the entire classification is built upon the worker caste and that identification of males and females usually depends upon association with workers. In spite of this, new species of ants have sometimes been described from males or females where the workers were unknown and, as a result, proper classification and identification have been made more difficult. For example, 17 species of North American legionary ants, comprising the subgenus *Neivamyrmex* of the genus *Eciton*, are recognized as valid, but in only 3 have workers, males, and females been associated. In one case workers and males can be identified, and in another workers and females, but 5 species are known only form workers and 7 species only from males.

Now, when we consider that taxonomy implies the classification of insects in all stages of development, the immensity of the task ahead becomes even more appalling. The characteristic egg mass of the gypsy moth can be readily recognized by anyone, and here and there some other insect is identifiable with reasonable certainty in that stage. In fact the eggs of some forms of anopheline mosquitoes have been found to show better distinctions than the adults (Kumm, 1941); but of the eggs of most species we know little or nothing, and when encountered they may not be determinable even to order. In the Aleyrodidae, or whiteflies, we identify the pupae, but as yet we are helpless when confronted with adults that are not associated with pupae. Increasing attention is being given to the larvae of holometabolous insects, especially Lepidoptera and Coleoptera, but we know less than 2 per cent of the described species in that stage; and in the Diptera, as well as in the larger heterometabolous groups, our knowledge of the immature stages is even more meager.

Inseparably linked with the countless problems of insect identity are those of nomenclature. These are a source of much irritation and confusion to workers who do not understand the essential nature of that relationship, and the whole scheme has been often and loudly condemned. Here again, however, as David Starr Jordan (1926) remarked, "The trouble is not with our system of nomenclature but with nature itself, so prolific with forms of life in comparison with the number of us trying to find out what really exists."

Gradual appreciation of the complexity of taxonomic problems has led, in comparatively recent years, to the exploration of new approaches and the application of new kinds of information in taxonomic thought and practice. As a result, insect taxonomy is no longer the province only, or chiefly, of the curatorial specialist, although it is still widely so regarded. Taxonomists have begun to understand that their concepts of unit segregates—call them species or anything else, as you will—become more accurate as they repsent the application of evidence beyond what is offered by the insect specimens themselves, and that, in the formulation of classifications, support or guidance must be sought from every source that has something to contribute. The admirable work entitled *The New Systematics*, which appeared under the editorship of Julian Huxley (1940), indicates the extent to which factors not apparent from a museum collection are now given consideration. To most systematists a taxonomic entity is no longer merely an aggregation of specimens; and insect taxonomy is gradually becoming the classification of insect populations based upon study and evaluation, not only of anatomical, but also of biological, physiological, ecological and genetic differences and likenesses, upon distributional limitations, and upon more specific reactions of the insect to its environment.

Unfortunately, detailed significant information of that kind is rarely available to the taxonomist in association with the specimens referred to him for identifica-

tion. Furthermore, the samples with which he has to work are usually too meager to give a satisfactory picture of the variability range in the populations represented, or they do not contain specimens of the sex or stage needed for positive identification. Not long ago an American entomological explorer wrote from Chile that a species of Scarabaeidae was doing extensive damage there and that he required an identification. He stated that the beetle was extremely abundant, that it occurred literally by the thousands everywhere, and that he was sending a sample. When this arrived it was found to consist of a single female *Cyclocephala*. In this genus, however, we can make identifications at present only from male specimens. An entomologist at a state experiment station recently referred for identification an insect sample accompanied by the report that extensive areas of grain were being severely damaged by the species. Although presumably it should not have been difficult to obtain abundant material, his sending comprised two specimens so badly battered that exact identification was not possible. These are not isolated instances; similar cases come to the attention of taxonomists regularly. In an earlier age identifications from such inadequate samples would perhaps have been made with little hesitation, but today the plea of the taxonomist is for more and more, well-preserved material accompanied by all the pertinent data he can get. In response to continued emphasis on this point some improvement is apparent, and occasionally requests for identifications are accompanied by excellent series of specimens. I recall a shipment of beetles that came recently from Alabama with the report that the species was causing serious damage to corn, velvetbeans, and cotton. There must have been nearly 1000 specimens in the lot and they were nicely preserved. The insect was the corn silk beetle, *Luperodes brunneus* (Crotch), of which a long series from a given population was much desired. I cannot refrain from adding, however, that in the larval stage that abundant species is still unknown and would not be identifiable unless associated with reared adults.

The purpose of this outline of the situation in taxonomy is to give proper emphasis to the difficulty of attaining the chief goal of taxonomists, accurate identification, which is at the same time the primary requirement in quarantine and nursery inspection; for a recognition of the present limitations in insect identification is essential to the development of the right perspective in the inspection service.

In considerable part the value of inspection work depends upon the extent to which the inspector understands how far he himself can safely go in identifying the material he encounters. Probably in no entomological activity is it more difficult to maintain a properly cautious attitude. Often extreme speed in examination is necessary. Anyone who will spend the hour from 5 to 6 on a Saturday afternoon with the Federal quarantine inspectors at the international bridge in El Paso, Tex., will be convinced of this. There is at that time a line of automobiles, many with tourists from the interior of Mexico, extending across the bridge and two blocks beyond, and there is an equally long line of pedestrians. In other lanes there are filled streetcars and busses, most of the passengers bringing groceries, especially vegetables and fruits, purchased on the Mexican side of the river. And yet, even under such conditions I have seen inspectors detect, and recognize with amazing accuracy, string beans infested with *Epinotia opposita* Heinrich, avocados containing larvae of the avocado weevil, *Conotrachelus aguacatae* Barber, or Irish potatoes lightly infested with *Epicaerus cognatus* Sharp, all pests that are not yet established in the United States. Through experience the inspectors become acquainted with an insect in its natural situation and in their conclusions they are influenced by factors other than the structural characters of the specimens. We must remember, however, that our knowledge of insect habits, host associations, and distribution is still far too meager to permit us to say that only this species or that can be responsible for a certain type of injury, that a given form occurs in a particular kind of association and in no other, or that plant material originating in one area cannot be infested with an insect known only from another region.

There is the continual danger that a hurried identification based essentially on such assumptions may actually be

merely a guess. The taxonomist, who usually has before him a great deal more work than he can properly attend to, is in a comparable situation. For both the inspector and the taxonomist nothing is more important than caution and the cultivation of that state of mind that keeps one constantly on the watch for the unexpected.

Because, under certain conditions, it is so easy to fall into the habit of making "snap" identifications it is always gratifying to note instances where commendable caution has been exercised. I should like to mention only one example of this which came to my notice a short time ago. An inspector on the staff of the State Entomologist of Arizona referred to Washington a lepidopterous larva that had been taken from an apple in quarantine inspection. He indicated that it did not agree completely with determined reference material he had, and that although he suspected it was the codling moth he could not feel altogether sure. Examination by the taxonomist proved that the specimen was actually a larva of that species but of an early stage in which the thoracic shield and sclerotized areas of the body are darker than in the mature larva. Whether the field worker in this case should have been expected to know the insect in any stage is beside the point. What is important is that he recognized his limitations which were defined by the reference material available to him and that he was not content to guess.

Of particular importance in quarantine and nursery inspection is an understanding of the correlation of structure and habits in insects. The inspector, whose facilities and taxonomic training are usually limited, can expect to make definite identifications for only a comparatively small number of species and only when these occur in restricted associations; but recognition of the more or less well-defined group to which an insect belongs may suffice to indicate the immediate action to be taken. Superficial differences, sometimes bizarre and very striking, between closely allied species, or between polymorphic forms of the same species, may tend to confuse the picture until the really significant characters have been determined; but as taxonomic work grows more critical it becomes increasingly evident that normally a rather close correlation exists between taxonomic affinities and habits in insects.

Positive determination of individual weevils of the white-fringed beetle group, which I have already mentioned in another connection, may be difficult even for the specialist, but it is probably safe to assume that any species of that complex, whether definitely identifiable or not, is of South American origin, that it is parthenogenetic, that its larva is a root feeder, and that it is a dangerous insect. Taxonomically, members of the leafhopper genus *Cicadulina*, which is represented in Africa, Arabia, Japan, Guam, the Philippine Islands, and South America, comprise an exceedingly compact group; and available information indicates that any species of the genus, known or unknown, that becomes established in a new area should be regarded as a potential pest and a possible vector of plant viruses.

Since there is so much taxonomy in quarantine and nursery inspection, a feeling for definite or group recognition of insects, which is so essential for the taxonomist, should also be one of the qualifications of the inspector. How well that aptitude can be applied will depend upon the practical guidance provided by taxonomists. Heinrich's (1919) studies of the various stages of the European corn borer and his discussion (Heinrich 1921), supported by numerous detailed illustrations, of Lepidoptera likely to be confused with the pink bollworm; Sim's (1934) explanation of the differences between the larva of the Japanese beetle and larvae of related species that occur in the same situations, coupled with Böving's (1939) detailed descriptions of the different larval instars of the Japanese beetle; Morrison's (1941) characterization of the oriental parlatoria scale in comparison with forms easily confused with it; and illustrated keys like one prepared by Capps (1939) to aid in the recognition of lepidopterous larvae intercepted by foreign plant quarantine inspectors, are illustrations of practical assistance given by taxonomists in restricted inspection problems. It must be understood, however, that even these individually trivial contributions are only possible as a result of basic taxonomic studies, such as the establishment of homologies in

structures of coleopterous larvae; the determination, through painstaking investigation, of the characters that are of significance in indicating affinities or distinctions between different forms in such microscopic groups as the scale insects; the development and perfection of setal maps of lepidopterous larvae that furnish the basis for group and specific differentiation in this stage; and the evaluation of the guides offered by genitalic characters in various orders of insects.

Such fundamental problems are receiving increasing attention, and it seems that taxonomy, with its present broad viewpoints, is moving in the right direction. However, in closing, I must again emphasize the imperfection of taxonomic knowledge, for in large part the effectiveness of the inspection services will depend on how thoroughly the complexities and present limitations of insect taxonomy are understood and on the exercise of the caution dictated by them.—1-19-42.

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The Present Status of Entomological Nomenclature[1]

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Entomological nomenclature is one of the many phases of systematic entomology which not only concerns the taxonomist but also the economic entomologist. The necessity for referring to objects by names is as old as human speech, and the need for always referring to the same kind of object by the same name became evident as soon as man began to move from place to place and to exchange ideas.

In the field of biology, Linnaeus was one of the first to become aware of the need for a uniform procedure for naming organisms. This was implied by him in his *Fundamenta Entomologia* (1736) and was expressed in a personal set of rules in his *Philosophia Botanica* (1751). Fabricius followed with another personal code for entomological nomenclature in his *Philosophia Entomologica* (1778) and Rudolphi did likewise in 1801 for the naming of parasites. Here the matter rested for nearly half a century during which time a large amount of work was appearing with little or no uniformity as to procedure.

By 1842 the situation became so critical that the British Association for the Advancement of Science appointed a committee to draw up a general set of rules for zoological nomenclature. The resultant code, often referred to as the "Stricklandian Code" from the name of one of the committee members, was a brilliant piece of work for its time and formed the basis of all future codes. By a curious coincidence, this code was adopted by the American Society of Geologists one year

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before its official adoption by the British Association. Although scarcely international in scope these rules fully justified Strickland's expressed hope "that they may lead to sufficient uniformity of method in the future to rescue science from becoming a mere chaos of words."

The American Association for the Advancement of Science, thirty years later, appointed W. H. Dall as a committee of one "to obtain an expression from the working naturalists of America, in regard to the nature of a set of rules for facilitating the decision of questions relating to nomenclature." The so-called "Dall Code" was published in 1877 and is still one of the best essays on zoological nomenclature. However, it was never formally adopted by the Association.

During the next two decades national codes were adopted by the Zoological Society of France (1881) and by the German Zoological Society (1894). An excellent code was prepared by the American Ornithologists' Union (1885) for bird nomenclature, and the International Congress of Geology adopted the so-called Douville Code which set the procedure for naming fossils.

By this time it had become evident that zoological nomenclature was an international matter and could only be handled by an international set of rules. Hence the First International Zoological Congress (Paris, 1889) adopted a code proposed by Raphael Blanchard. This was actually the beginning of our present International Code. The Second International Congress (Moscow, 1892) readopted the Blanchard Code but unfortunately it was not generally accepted outside of France and America for nationalistic and perhaps other reasons.

Thus, in the year 1895, according to Stiles, "English systematists were following the Stricklandian Code; French systematists were following the International Code; German systematists were following the German Code; American systematists were divided between the Stricklandian, the A.O.U., the Dall, and the International Codes; systematists in special groups were in some cases following special or even personal codes; and systematists of Italy, Russia, and some other countries were following either the the International or some other code."

Out of this apparently hopless confusion emerged an international committee of five members: R. Blanchard (Paris), J. V. Carus (Leipzig), F. A. Jetink (Leyden), P. L. Slater (London), C. W. Stiles (Washington) appointed by the Third International Zoological Congress (Leyden, 1895). This committee made a careful study of all existing codes and, after being increased to fifteen members at the Fourth International Congress (Cambridge, 1898) finally brought forth the present rules (International Rules of Zoological Nomenclature). These rules were formally adopted by the Fifth International Zoological Congress (Berlin, 1901) and were edited in English by Stiles, in French by Blanchard, and in German by Maehrenthal. At the Sixth Congress (Berne, 1904) the committee of fifteen was made a permanent commission with five members retiring every three years.

The International Commission is an advisory body only. It performs an essential function in receiving recommendations or proposals from any and all scientists in the world. The executive committee considers such proposals at least one year in advance of an International Congress meeting and then refers them to the Commission. The Commission then submits an "opinion" (136 have now been submitted) which is published in a few scientific periodicals selected with a view to the greatest distribution to working scientists in all fields throughout the world. Official action must then await the next meeting of the International Zoological Congress.

The above system, although insuring conservatism, has proven to be very ponderous in action. Under ideal conditions it should prove adequate, but world conditions have caused interminable delays and some of the most pressing questions in modern nomenclature remain unanswered. With ever-increasing demands upon taxonomy it is imperative that the weaknesses of the present situation be corrected.

It is gratifying to observe the part that has been played by entomologists in the development of rules and procedures for zoological nomenclature. As mentioned above, Linnaeus first implied the need for such rules in an entomological work. The same was true of the Fabrician Code. In 1858, the Entomological Congress at Dresden formulated a series of laws for

entomological nomenclature (Berl. Ent. Zeitschr., 2: xi-xxii, 1858). This *Codex Dresdensis* found considerable opposition within the membership of the Entomological Society of France, and at the instigation of M. Reiche the matter was given special consideration by the Society. This consideration resulted in a critical review and discussion of the Dresden laws by Amyot (Ann. Soc. Ent. France, (3)8: 571–606, 1859) and Reiche (Ann. Soc. Ent. France, (3)8: 607–614, 1859).

The first American entomological codes were those of the entomological section of the American Association for the Advancement of Science (published in 1876 and 1877). These rules were proposed because of lack of agreement among American zoologists on the interpretation of the "Stricklandian" Code and the fact that the Zoology Section of the A.A.A.S. had long delayed consideration of a set of rules. LeConte, Saunders, and Riley (1876) summarized the situation as follows: "It has been, and will be objected to, by some, that no rules that do not apply to the whole realm of zoology, or that do not emanate from Section B of the Association can have any weight or do any good. While admitting that it is desirable that any rules adopted by us should accord, as far as possible, with those governing zoologists generally, we believe that on account of the great profusion of insects and the many forms under which the same species presents itself, as well as on account of the diversity of opinions now held on the subject by entomologists, our science not only needs some rules that are unnecessary in other departments of zoology, but is to-day most in need of generally recognized rules. The greater necessity to entomology than to any other branch of zoology of a code of rules, is manifest in the preponderance of entomologists on the committees appointed to draw up the British Association Rules. We have waited in vain for three years for the committee on Nomenclature in Section B to report, and consider that by first adopting rules for our own use and good, we shall in so much assist that committee in eventually making its report, by indicating our own wants and preferences." That the efforts of these entomologists had the desired effect was attested by the fact that the Dall Code appeared in 1877.

Soon after the adoption of the International Code its shortcomings became apparent and Banks and Caudell (1912), after circularizing and consulting a great many entomologists, drew up "A Code of Nomenclature for Use in Entomology" because "most existing codes fail to cover in a definite manner many points that continually arise in entomological work, or the language used is of such a broad or indefinite scope as to require official interpretation to make the meaning evident." Although not official, this code is an excellent one and might well be followed in cases which are not covered by or may be ambiguous in the International Code. For example, primary and secondary homonyms are clarified, publication is defined, categories of names are grouped, names of higher categories are considered and the selection of types is given very full consideration.

Still another important clarification of the rules has come from the entomologists. The British National Committee on Entomological Nomenclature, originally appointed at the International Congress of Entomology (Oxford, 1912) set out in 1924 to "elucidate and simplify the articles of the code." The report of this committee was circulated in 1925, and was also brought before the Third International Congress of Entomology at Zurich in July of that year, when at the last meeting of the Congress, held on July 25, the following resolution was passed, *nemine contradicente:* "The Congress resolves that the revised rules of Nomenclature placed before the Congress by the British National Committee be accepted as a basis for further deliberations regarding a revision of the rules of Zoological Nomenclature." After further modification, this report was published (1928) with the invitation that all entomologists seriously interested in nomenclature give it their fullest consideration and submit criticisms.

This British Code still stands unadopted after more than ten years. It had been hoped that this and other subsequent reports, as well as opinions of the International Commission might have been incorporated into a completely revised International Code of Zoological Nomenclature. However, even during the last period of world peace and relative international co-operation this goal was

not achieved. Now, with most of the world divided in a great war that promises to be long and bitter, hope for international action must, at least temporarily, be abandoned. Is it not, then, time for American entomologists to formulate and adopt their own program? Such a program should be sponsored jointly by the Entomological Society of America and The American Association of Economic Entomologists. It should embody all the principles now included in the International Code so that none of its hard won gains should be lost. However, it should go further. It should cover the names of categories higher than the family, clarifying the questions of endings, type genera, priority or usage, etc. It should more thoroughly treat the categories lower than the species, primary and secondary homonyms, specific types, the question of what constitutes publication. Perhaps the British Entomological Code should be adopted. At least it might serve as a basis for study. In any event, uniformity of practice by American systematists would go a long way toward the promotion of ultimate uniformity in world practice.

In closing I should like to raise one other question. It involves the law of priority. The law of priority has been called the "keystone of nomenclature" (Stiles). The acceptance of the first name proposed is so eminently logical and just that the principle has pervaded all nomenclatural practice. True, there are those who would bow to general usage and Heikertinger (1928) has gone so far as to advocate the substitution of his "Kontinuitätsprinzip" for the law of priority. According to this view the monographer selects the name in common use or the name which causes the least disturbance in scientific literature. Many systematists are unconscious supporters of a modified principle of continuity for it is instinctive to rebel against changes in familiar and long established names because of technicalities involved in the priority of the name in question. Still it has been pointed out that nomenclature should be practical, not sentimental, and all subjective considerations should be eliminated. In other words, the nearer we can approach a mechanical system, the nearer we will have arrived to our goal of stability.

With this viewpoint the speaker is in full agreement. However, the law of priority (in fact all nomenclature) is merely a means to an end, and no law should be completely inflexible or it may defeat its own purpose. This fact was recognized by the 9th International Congress of Zoology which empowered the International Commission to suspend the Rules in any given case where, in its judgment, a strict application would result in greater confusion than uniformity. By this authority the Commission has, from time to time, set aside the law of priority and the rules for establishment of genotypes, etc. However, this has only been done on a very small scale and each case has required years of preliminary procedures. Therefore, I would like to suggest that the American entomologists prepare a list of *nomina conservanda*, of perhaps 250 names of species which they will accept without prejudice to the law of priority. This list should include our more important economic species as well as others which are commonly used for biological, morphological, or other purposes which have caused a considerable amount of literature to be built up about their names. The list might be voted on in much the same way as our current lists of common names. If the International Commission ever functions again, the items on the list might be submitted for approval a few at a time. Meanwhile, until action by the Commission, American entomologists would agree not to change the specific names for any nomenclatural reason whatsoever.

In any event, whatever the value of these particular suggestions, and they are by no means new or original, I believe we should have an active American Committee on Entomological Nomenclature; a committee representative of our major entomological societies and institutions, and of the various geographic areas in our country. In my opinion this committee should thoroughly examine the whole question of entomological nomenclature and prepare a full report for the consideration of all American entomologists.—7-23-41.

Status and Functions of the Section of Plant Quarantine and Inspection

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At the 52nd annual meeting of the American Association of Economic Entomologists held at Philadelphia, Pennsylvania, December 27 to 31, 1940, there occurred some discussion in the Section of Plant Quarantine and Inspection with respect to its programs. The thought was expressed that the Section was resorting to something not far removed from artificial respiration; that the lack of voluntary papers and adherence to the invitation paper type of program had become recognized throughout the Association to the end that the Section was serving very little purpose in the direction of helping younger entomologists to develop in the field of plant quarantine and pest control problems. As a result of this discussion a special committee was appointed to study the questions raised in the course of this discussion.

The Section of Plant Quarantine and Inspection shares with the Section of Apiculture the position of oldest section in the Association. During the years this Section has been in existence it has acquired certain traditions. The effect of the background on the programs of the Section may be better understood by the following brief account of the history of the Section of Plant Quarantine and Inspection.

In the city of Chicago on January 29, 1897 through the efforts of Dr. S. A. Forbes, at that time Professor of Zoology and Entomology at the University of Illinois, there took place a conference attended by the official entomologists or experiment station horticulturists of Ohio, Indiana, Illinois, Missouri, Iowa, Michigan, Minnesota and Wisconsin. This conference considered measures, including inspection and certification of nursery stock for the protection of horticulture of that region, against the San Jose scale. Other conferences followed along the same line until on January 4, 1901, a permanent organization was effected. Following that action steps were taken preliminary to a general conference of official State Entomologists of the United States and Canada to be held in Washington in connection with the meeting of the American Association of Agricultural Colleges and Experiment Stations.

It is further disclosed by the records that the first annual meeting of the American Association of Horticultural Inspectors was called to order at the Ebbitt House, Washington, D. C., November 11, 1901, by the Chairman, Dr. S. A. Forbes. At that meeting 15 states were represented as follows: Connecticut, W. E. Britton; Delaware, W. Webb; Georgia, W. M. Scott, W. Fiske; Illinois, S. A. Forbes; Indiana, J. R. Troop; Iowa, H. E. Summers; Maryland, A. L. Quaintance, J. B. S. Norton, Professor Blodgett; Massachusetts, H. T. Fernald; Missouri, J. M. Stedman; New Jersey, J. B. Smith; New York, G. A. Atwood; North Carolina, F. Sherman; Ohio, F. M. Webster; Pennsylvania, J. Hamilton, E. B. Engle; Virginia, W. B. Alwood, J. L. Phillips; Wisconsin, W. A. Henry.

At the 4th annual meeting, also held in Washington, November 14–16, 1905, action was taken allowing representatives of the American Association of Nurserymen access to the meetings and all discussions of general interest.

It is not entirely clear just when the Horticultural Inspectors discontinued meeting at the same time and place as the American Association of Agricultural Colleges and Experiment Stations but in the program for the 21st annual meeting of the American Association of Economic Entomologists beginning December 28, 1908 in Baltimore under the caption "Other Meetings" the following appears: "The AAAS and its affiliated societies will hold meetings throughout the week." "The American Association of Horticultural Inspectors will hold sessions at 8 p.m. Tuesday, December 29 and at 9 a.m. Wednesday, December 30."

When the 24th annual meeting of the American Association of Economic Entomologists was held in Washington, Dec. 27–29, 1911, there was discussion of forming sections. Dr. R. A. Cooley, then State Entomologist of Montana, said "In an entirely informal way and not to further

encumber our records, it seems to me desirable that we as an Association have in mind the practicability or desirability of dividing the Association conservatively into sections. If the Horticultural Inspectors are affiliated with us at a later time, it would seem desirable to have a section of Horticultural Inspectors. If the Apiary Inspectors Association is affiliated it would seem to be desirable to have such a section." Later in the same discussion he went on "There has been an increasing tendency to crowd our programme. The discussions following papers should be more deliberate—in some cases more extended. I believe it might be well to have a standing committee on programme and that papers presented might be reviewed. This may have been previously discussed. It might be well to classify our programme, so that we will be following some natural and logical classification and, as individuals, attend one or another section, according as our interests lead us. I have nothing definite in mind and yet I feel certain that the tendency of affairs is in that direction and that, eventually, we will arrive at some such division of our programme—a discussion of insecticides, perhaps, in one section, life histories in another, methods in another—or some other such classification." At that time—1911—the membership of the Association was 136 active members and 169 associate members. It is interesting to note that in 1911, with a total of 305 members the Association was discussing the problem which now confronts us with a total of approximately 1,550 members. At the 25th annual meeting at Cleveland, January 1–3, 1913, action was taken whereby the Section of Horticultural Inspectors and the Section of Apiary Inspectors were duly affiliated with the Association. There was a report by two committees to give effect to the proposed affiliation. A committee consisting of W. E. Britton, Chairman, and Wilmon Newell and A. W. Morrill proposed an amendment to the constitution which made eligible for membership in the Association "horticultural or apiary inspectors employed by the general or state governments or by the State Experiment Stations or by any agricultural or horticultural association, and all teach ers of economic entomology in educational institutions and other persons engaged in practical work in economic entomology." The other committee, T. B. Symons, Chairman and A. F. Burgess and T. J. Headlee, reported on the plan of affiliation. This plan briefly provided that "After the affiliation has been accomplished, the annual meetings of the American Association of Economic Entomologists shall be arranged so that the Horticultural Inspectors may meet as the section of Horticultural Inspection, and the Apiary Inspectors may meet as the section of Apiary Inspection and the programs shall be made up so that as few papers as possible of mutual interest shall be presented at the same time before the American Association of Economic Entomologists and its sections. The American Association of Economic Entomologists further agrees that one vice-president of its Association shall be a recognized Horticultural Inspector and he shall have general direction over, and preside at, the meetings of the section of Horticultural Inspection and a similar arrangement shall be put in force for the section of Apiary Inspection."

On December 31, 1913, to January 2, 1914, at the 26th annual meeting of the Association, the program included the two newly formed sections. The Section of Apiary Inspection met at 10:30 a.m. January 1, 1914, with Wilmon Newell as Chairman and E. F. Phillips the secretary. The Section of Horticultural Inspection met at 1:30 p.m. the same day with E. L. Worsham as Chairman and J. G. Sanders as secretary. The official age of this section, therefore is 29 years but its actual age during which it has been giving consideration to problems falling within the field covered by its title, is 41.

The records do not disclose the official action by which the name of the Section was changed from the Section of Horticultural Inspection to the Section of Plant Quarantine and Inspection. At the 36th annual meeting of the Association which was held at Cincinnati, December 29, 1923 to January 2, 1924, the program indicates that the section of Horticultural Inspection met on the afternoon of December 29. The following year, at the 37th annual meeting of the Association in Washington, D. C., December 31, 1924, to January 3, 1925, the Journal records that the Section of Plant Quarantine and Inspection met on December 31,

1925. Evidently at the meeting in Cincinnati the action was taken to change the name as indicated.

It was along about this period that the state plant quarantine officials were organizing themselves into what became known as the regional plant boards. The Western Plant Board was organized in 1919 and the other regions were organized in the years that followed, the National Plant Board organization being perfected at a meeting in Washington on June 25, 1926. As the plant boards began to take shape and to function they necessarily exerted an influence on the programs of the Section of Plant Quarantine and Inspection. It may be noted that there is a certain amount of similiarity between the subject matter presented at certain of the plant board meetings and at the meetings of the Section and study of the programs of the ensuing years indicates considerable effort was being exerted by the officials of the Section to maintain interest in it and to keep up the standards of programs presented at its annual meetings. To do this, more and more emphasis was placed on the invitation paper type of program; naturally to furnish interest and to hold the attendance it was logical to select as the authors of these invitation papers persons well known in the Association or to its members and thus the caliber of the programs was maintained at a high level. The field of plant quarantine and inspection in this country, however, during those years, was undergoing great development. Many young entomologists were finding employment along these lines and these men found no avenue readily available in the Association through which they might express their interest in the work. They were not invited to appear on the program of the Section of Plant Quarantine and Inspection. They were probably somewhat awed by the length of the programs of the main sessions and combined with this there may have been a feeling of some restraint toward offering their comments and observations before the main group of the Association. It was recognition of this factor in part which led to the discussion at the Philadelphia meeting previously referred to. The members present at that meeting felt that the Section was not fulfilling its responsibility toward the membership of the Association. As the Association grows larger, the importance of the attitude of the Section toward its programs naturally becomes more important. The Committee appointed at the Philadelphia meeting to study these problems entered upon their studies with the conviction of the desirability of maintaining interest in the programs of the Section; coupled with this, however, the Committee was also definitely of the opinion that it would be desirable to indicate to younger entomologists engaged in plant quarantine and enforcement or pest control activities, that this section represents a place where they are welcome to present their comments and observations on the work in which they are engaged. It is the belief of the committee that the responsibility of the section to economic entomology can only be met by recognition of the importance of the function of the development of economic entomologists in the lines in which this Section is particularly interested.

In the light of this interpretation of the responsibility of the Section and in view of the field for expression which is made available by the various plant boards, the Committee feels that encouragement should be given to the voluntary paper type of program for the Section. Recommendations to this effect are inspired by the belief that economic entomologists will find many subjects to be presented in programs of this Section dealing with biological phases of plant quarantines and pest control, with new methods of application with the development of which they have been associated and with the results of practices they are engaged in, which should be published for the benefit of economic entomology.—1-26-42.

Recent Quarantine Adjustments Giving Increased Consideration to Biological Findings

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A brief reference to the history of quarantines is necessary in order to understand the problem as stated in the title and to give due credit to those agencies responsible for its development. In reviewing this history it is interesting to note the alarm and concern that the establishment of numerous quarantines gave in the various states throughout the country. A few of the quarantines were biologically sound but it is apparent that individuals lacking fundamental training were responsible for the establishment of many of the early quarantines which caused so much trade barrier comment. Some of these quarantines are still found on the statute books.

In 1913 the American Association of Economic Entomologists, and in 1915 the Federal Horticultural Board of the United States Department of Agriculture suggested that a more careful study be made of pests before quarantines were promulgated. In 1917 the Association of State Horticultural Inspectors and the American Association of Nurserymen made similar proposals. In 1924 suggestions were made by various groups, and in 1928 the Committee on Uniform Requirements for the Interstate Movement of Nursery Stock of the Central Plant Board made definite recommendations along biological lines for the general quarantine situation. This committee pointed out that this problem had been confronting them for at least twenty years. Some groups tried to effect federal control of all quarantine and regulatory work. Because of the federalization aspect pointing towards considerable centralization, many of the efforts were voted down from time to time by the various important organizations.

No doubt the real beginning of concrete action along this line started when G. H. Hecke, Director of Agriculture of California, organized the Western Plant Quarantine Board at Riverside, California, in 1919. Little did Mr. Hecke at that time, or probably anyone else, visualize the importance that this organization was to occupy in plant quarantine affairs of the United States. No doubt this movement can be considered one of the greatest inter-state cooperative developments in the history of agriculture in this country. The original organization comprised British Columbia, Hawaii, and the northern district of lower California and Mexico as well as the western states. The splendid progress made in this organization greatly influenced the spread of the idea to other parts of the country.

In these earlier days, the relation of biology to quarantine establishment was not stressed so much as uniformity in the promulgation and application of quarantines. The important development is the fact that through official conferences, quarantine officials and entomologists of the various states became acquainted with one another and a feeling of mutual respect developed. It is readily recognized that in the establishment of a plant quarantine one of the prerequisites is a thorough understanding among officials of the importance of organization. And although biological facts are absolutely essential, they really are secondary. Entomological, biological and ecological facts would mean nothing if friendliness, the spirit of cooperation and understanding through organization did not come first.

In 1925 the regulatory officials of the central states met at Lafayette, Indiana, and formed the Central States Advisory Plant Board which is now known as the Central Plant Board. The original states of this group included North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa, Mississippi, Wisconsin, Illinois, Michigan, Indiana, Ohio, and Kentucky.

In 1925 the regulatory officers of the Atlantic states organized the Middle Atlantic and Northeastern States Plant Conference Board group composed of the quarantine officers of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, Pennsylvania, New York, Delaware, New Jersey, West Virginia, Maryland, and Virginia. This group is now known as the Eastern Plant Board.

In 1925 the regulatory officials of the southern states called a meeting and in 1926 a permanent organization of the

southern states became a reality including the states of Texas, Oklahoma, Louisiana, Arkansas, Alabama, Mississippi, Florida, Georgia, Tennessee, North and South Carolina. This is the Southern Plant Board. The e were the beginnings of the organizations which now represent the four sections of the country as regional plant quarantine boards.

This led to the organization of the important National Plant Conference Board. In December 1925, at a meeting of the American Association of Economic Entomologists held in Kansas City, two members from each of the duly constituted regional organizations, that is—the Western Plant Quarantine Board, the Middle Atlantic and Northeastern States Plant Conference Board, the Central States Advisory Plant Board, and two members from the Federal Horticultural Board organized the National Plant Conference Board. The southern group had not as yet organized but sent two members to the meeting. The membership of the original National Plant Conference Board included Lee A. Strong, at that time Assistant Director of the California Department of Agriculture and representative of the Western Plant Quarantine Board; M. L. Dean, Director of the Bureau of Plant Industry of the Idaho Department of Agriculture representing the Western Plant Quarantine Board; C. L. Marlatt, Chairman of the Federal Horticultural Board; and E. R. Sasscer, Executive Officer of the Federal Horticultural Board, representing the Federal Horticultural Board; W. A. McCubbin, Plant Pathologist of Pennsylvania Department of Agriculture; and W. C. O'Kane of New Hampshire, representing the Middle Atlantic and Northeastern State Plants Conference Board; S. B. Fracker, State Entomologist of Wisconsin, and Frank N. Wallace, State Entomologist of Indiana, representing the Central States Advisory Plant Board; W. A. Harned of Mississippi; and George Becker, Chief Quarantine Inspector, State of Arkansas, representing the southern states at this first meeting of the National Plant Conference Board. L. A. Strong was its chairman. These men and others with whom they were associated in their Regional Plant Boards are to be considered the real pioneers in organized effort where biologically sound principles in quarantine were to be applied. This Board was important in maintaining contact between the federal government and the states.

The present National Plant Board consists of eight members, two being chosen from each regional board. Unification in the promulgation and application of quarantines in this country is the main objective. There are at least 49 organizations in the United States empowered to establish, modify, or revoke quarantines. Hundreds of outside agencies try to influence action along these lines. The pull and haul of so many different factors gives an idea of the difficulties encountered.

It can be proved with little difficulty that very recently there has been a definite tendency towards the betterment of the general quarantine structure both state and federal in the United States. In the foregoing paragraphs the intent is to point out the desirable developments indicating the tendency to recognize the need of accurate biological data for establishing quarantine. Some of the weaknesses of the present and past quarantine structure must necessarily be discussed.

So far this paper has dealt in a general way with the history and discussion of the past situations relative to early organization and factors influencing quarantines. This leads to the conclusion that organization, survey and biological knowledge are the basic features of the general problem at which one must finally arrive if quarantine difficulties are to be alleviated.

For the purpose of further showing the influence and gradual recognition of biological research on the general development the following four phases of the subject will be presented:—(1) Principles of Plant Quarantine; (2) a discussion of past difficulties; (3) specific citations of what is now being done; (4) what more can be done.

It is our belief that the Principles of Plant Quarantine as promulgated by the National Plant Board are becoming more thoroughly recognized from day to day. The main Principles of Plant Quarantine have been repeated a great many times. However, we believe that the more often the outstanding Principles of Plant Quarantine are repeated, the more likely will the older regulatory officials recall them and the younger and oncoming regulatory officials study and apply them.

In general it is agreed by all that when

quarantines are established they must have had a sound biological basis for their establishment or they could not be maintained. If an emergency requires the establishment of a quarantine before satisfactory biological data are available, provision should be made as soon as possible for extension or revision based upon the biological knowledge.

Cooperation in some states, for one reason or another, between the research men and the regulatory men, is impossible. However, when such a condition exists the department that exercises the right to establish a quarantine should have the authority to demand cooperation in carrying on biological research on the project. Cooperation with research departments is absolutely essential not only in order that the quarantine be more efficient but that the restrictions might be lessened when possible. This cooperation might even lead to the supplying of funds for carrying the research project. A need for research, however, should not be permitted to delay the establishment of a quarantine believed by authorities to be desirable, thereby jeopardizing the objectives that might otherwise have been attained. Further, the Principles state that as conditions change, or as further facts become available, the quarantine should be properly modified, either by inclusion or restriction necessary to its success or by removal of the requirements found not to be necessary. The obligation to modify quarantine as conditions develop is a continuing obligation that should have countinuing attention. If a quarantine has attained its objective, or if the progress of events has clearly proved that the desired end is not possible of attainment by the restrictions adopted, the measure should be promptly reconsidered, either with the view of repeal or with the intent of substituting other measures.

I repeat this all important phase of Principles of Plant Quarantine dealing with validity "A quarantine established for the purpose of attaining an objective other than that which it indicates or defines is open to serious criticism, even though the actual objective is itself desirable."

Biological findings used in applications of quarantine are now definitely bringing about greater uniformity and greater efficiency in the promulgation of plant quarantines. The National Plant Board acts as a clearing house of information on quarantine and regulatory subjects. The National Plant Board today also acts in bringing together the quarantine authorities and the research groups in an effort to make conclusions on a sound basis.

For instance, several states have indicated their intention to revoke their potato tuber worm quarantines after a study of the general biological information now available. It is rather definitely concluded by some that two potato tuber worm quarantines recently enacted are unnecessary. It is evident that the problems concerning potato shipments to these states could have been satisfied through enactment of proper grading laws.

Politics have been blamed and rightly so for some of the undesirable quarantines established in the earlier days and some of these quarantines are still in effect. However, a recent general survey indicates that quarantine activity is becoming practically void of political influence or interference.

It is apparent that some of the older quarantines were established by individuals who were not entomologists. They had no conception of what was meant by sound biological facts nor did they make any attempt to obtain opinions from those who were so informed. The present tendency throughout the country indicates that only well trained men are now being appointed to take charge of regulatory and quarantine work.

Numerous undesirable quarantines still on the statute books in a number of states can be attributed only to plain laxity or indifference on the part of those responsible for their possible revision or revocation. Numerous examples of this could be recalled. However, to do so would be embarrassing to some officials who, without question intend to make changes knowing that they are being scrutinized and seriously criticized. It should be remembered that when a quarantine has outlived its usefulness, it should be revoked or modified depending upon the circumstances. Those in charge of regulatory work should review very carefully these quarantines. Organizations and individuals of the state interested in the quarantine should be conferred with at least once a year. A number of quarantine officials during the

last year or two have calmly admitted the facts as they are described herewith and have now proceeded to eliminate *paper quarantines*. Such information has been divulged confidentially between various officials and obviously could not be disclosed herein. One interesting comment came to our attention to the effect that a particular state quarantine was not being revoked because of lack of funds to print the notices necessary by law for revocation. Still it is a well known fact that this quarantine costs many individuals, farmers, industrialists, and state inspection organizations a considerable sum of money to live up to from year to year.

Another interesting example is of a state European Corn Borer Quarantine being maintained where the insect is moving across the country to new territory so rapidly from year to year that the officials responsible have been unable to revise their quarantine fast enough to keep up with the pest.

Personal differences of opinion often enter into the picture. Although these differences of opinion have been honest, the result has led often to the establishment of bad quarantines.

Some entomologists in charge of quarantine systems are imbued with the idea that they cannot take action in one direction or another without the approval by the majority or unanimous vote of various agricultural groups who may be affected by the quarantine. It takes the average quarantine officer a great many years of study to find out the fundamental basis for establishing quarantines and to learn to know something of what is meant by biological and ecological facts. For a regulatory official to establish quarantines on such a basis therefore, that is votes of confidence, etc., by various industrial groups affected, is ridiculous. For a group of farmers or other laymen to determine within half an hour the procedure to be taken and the vote by them to be the determining factor as to whether a quarantine should be established, modified, or revoked is ill advised. Again, such meetings are often packed and hence the action taken is prejudiced.

Public hearings in connection with quarantine establishment, revision, or revocation have slowed down the procedure considerably and have brought about considerable misunderstanding. Lack of time to properly explain details and biological information has been one of the reasons. The present tendency has been to limit public hearings and then only to give the necessary statistical information. This is, in our opinion, a desirable recent development.

Quarantine officials who rely entirely upon public hearings in their quarantine procedure are to be severely criticized. It is apparent that the majority of the states now maintain regulatory officials who have the power to make the final decision with respect to quarantine treatments and base such action on factors most important for the welfare of the country, state or the community affected.

The general inherent opposition of the public to any type of regulatory or quarantine work is obvious. Recent publicity and educational work carried on in regulatory systems particularly through universities has alleviated this situation considerably.

Lack of knowledge in the older days was naturally the primary and most important difficulty. With the tremendous amount of research now going on in state institutions and various govenmental agencies, it is possible to obtain information on most any of the insects or diseases now under quarantine. This information should be used in revising or treating quarantines so that there will be sound biological reasons for their existence. It might be well to point out here that with the present war emergency the question of funds for research may be one of the first items on the list to be eliminated for the present necessary "all out war effort." Careful study should be made immediately by research groups and regulatory officials to determine which research projects are the most desirable to maintain. Congress and state legislatures should then be pressed to appropriate the requested funds.

Many of the old state quarantines are outmoded because of new transportation facilities. Possibly our worst enemy today is passenger transportation agencies such as automobiles, trucks, busses, airplanes, etc. Immediate and careful attention must be given to these carriers in relation to domestic quarantines and regulations. Some of the old quarantines cannot, of course, be made effective because of lack of inspection and checking facilities. A

great many quarantine and regulatory organizations have not kept up with the new transportation developments.

During the past, lack of funds to enforce quarantines has caused many justified criticisms. Recent elimination of certain federal quarantines by the Bureau of Entomology & Plant Quarantine, because of lack of funds to enforce them has caused the establishment of numerous state quarantines to cover the same pests. However, it is obvious that some of these states are in no better position to finance the enforcement of these quarantines than was the federal government.

The present war has increased difficulties with respect to quarantine operation. This question is of immediate concern and must be carefully studied.

Quarantine committees established by the Regional Boards to act as clearing houses for consideration of new state quarantines and regulations and to review old quarantines have produced desirable revisions and the revocations of numerous quarantines. Recently the Western Plant Board voted unanimously to eliminate the alfalfa weevil quarantines. The National Plant Board voted 7 to 1 to revoke alfalfa weevil quarantines and the Central Plant Board voted 10 to 3 for revocation. Careful study of recently conducted research was responsible for this final action. Recent studies generally indicate that the potato tuber worm quarantines may be treated likewise. Applying sound biological knowledge obtained, several states have revised or revoked European corn borer quarantines in compliance with National Plant Board "Principles of Plant Quarantine."

In reviewing the recent minutes and procedures of the regional plant boards and the National Plant Board, frank expressions of opinions based on facts regarding new infestations of insects and diseases in the several states are found. This development will lead towards continuing confidence between the states and may avoid future retaliatory legislation. This is a very noticeable new feature of quarantine development. Biological facts were discussed in relation to practically all insect and disease problems brought up for discussion at Board meetings during the past five years.

Although many of the items discussed herein do not deal directly with the question of biology as related to quarantines, it is deemed desirable to consider some of the other factors as related to quarantines.

Reciprocal agreements between approximately 26 states covering numerous regulations have made a tremendous difference in the general attitude of the various states towards one another. There is no longer a reluctance to discuss with full frankness the danger and potential menace of the many pests and diseases involved between the states. Reciprocal agreements have shown regulatory officials that there is a way out for many of these difficulties. So far as plant quarantines are concerned, retaliation is practically out of the peiture. The most important factor, that is—biological evidence, now leads when quarantine action is considered.

Recently many resolutions have been passed by the various boards requesting the Bureau of Entomology and Plant Quarantine and other research institutions to obtain biological information of value to the quarantine officials for consideration in establishing, revoking, or revising quarantines.

Several recent valuable papers have been presented recommending the application of commodity treatments for the alleviation of quarantines. Today there are a number of treatments available which are simple in application and reasonable in cost which are much more effective than quarantine or inspection.

Regulatory officials are beginning to recognize that inspection in itself as a measure to meet quarantine requirements is ridiculous under many of the circumstances involving present quarantines.

At recent regional and National Plant Board meetings, resolutions were considered suggesting that the time of duration of a quarantine be stipulated at the time of enactment and that at the end of such a period, possibly five years more or less, these quarantines should be subject to review by special or quarantine committees of regional plant boards. Recommendations then would be given to the states involved and the quarantine eliminated or revised accordingly. There is no question but that this is one of the most important considerations to come before the plant boards for many years. Research specialists in the fields of biology

and ecology would necessarily be heard from at such reviews.

Surveys to determine the presence and distribution of insects and diseases should be established as the first important movement in consideration of any action to be taken with respect to quarantine enactment. Such surveys to be of value to quarantine or control officials must necessarily be accompanied by considerable biological data. It is suggested by many that such surveys and investigations should be made by an unbiased organization such as the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture.

A very important recent tendency is to give more consideration to the study of pests in foreign countries. Many entomologists and officials of the Bureau of Entomology and Plant Quarantine have stressed this for a considerable time. However, it now seems to be the prevailing opinion that the sending of well trained scientists abroad to study pests which have not as yet been introduced into this country is fundamentally one of the most important procedures to follow. Under present war conditions, this may not be possible. It is apparent however, that such a development will be an actuality when possible.

Another recent development is that bacteriology has come into the picture of biological control. This slant may also alleviate some of the rigorous measures advocated in plant quarantines. The application of the results of such studies are fundamentally sound, and quarantine officials are giving these phases of science increased consideration and support.

Much new machinery has been developed during the past few years for the control and eradication of insects. This also has a tendency to alleviate the quarantine situation at least to some degree.

Many regulatory officials and research individuals have recently agreed that preliminary reports of research under way should be made available with proper qualifications to control and regulatory officials and thus prevent losses where possible. This is a subject which deserves more consideration.

There is a general tendency to establish preventive entomology through surveys as outlined by P. N. Annand of the Bureau of Entomology and Plant Quarantine in a recent paper presented to the National Plant Board. This is probably one of the most important recent developments and it should go far towards giving information which should assist the officials responsible for the enforcement of quarantines.

It is recognized that many simple rules and regulations can be established by certain states now maintaining quarantines. The simple rules and regulations are not nearly as drastic, severe and far reaching in effect as many of the present quarantines. A number of quarantines are in the process of being revoked because regulatory officials responsible for their enforcement have found that simple rules and regulations could cover the requirements just as well. On the other hand it is obvious that many present rules and regulations are unnecessary.

It is recognized that in the future fewer quarantines will be necessary provided certain states establish better qualified inspection systems, establish terminal and transit inspections where needed and in general make state inspection systems more reliable.

Each and every state in the Union should assist the Domestic Quarantine Division of the Bureau of Entomology and Plant Quarantine in the transit inspection procedure. Many states benefit by the work of the Domestic Quarantine Division but few contribute anything toward its support, cooperatively or otherwise. Lack of state funds has been a very serious factor in making it possible for some states to control or restrict the movement of certain pests. This results in quarantines being established against it by other states.

To resort to federal control of all quarantines is not desirable. However, there are many instances where the undesirable features of quarantines could be eliminated if the quarantines were under federal administration.

It is apparent from the foregoing that we are definitely and carefully, possibly a little slowly, moving in the right direction. Certainly all industries affected by quarantines should recognize this recent development and give due credit and support to quarantine and regulatory officials responsible for the trend.—1-26-42.

What Regulatory Officials Should Do to Simplify and Coordinate the Plant Quarantine and Regulatory Structure of the United States

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The spread of insect pests and plant diseases by human intercourse and by commerce between nations has resulted in losses of enormous proportions to the people of the United States. The importance of the pest risk which not infrequently attends the importation of plants and plant materials, and the role which the vessel or other vehicle plying in commerce between the nations may play in transporting these pests as stowaways, or otherwise, were not appreciated, nor the consequent danger fully recognized, by our forefathers. The desirability and need, however, for controlling human immigration were recognized by them long before any serious attempts were even made to prevent the entry of undesirable insect pests and plant diseases from foreign lands; or to eradicate such pests after they had gained entry before they had become widespread and firmly established.

The need for preventing entry of undesirable human aliens who desired to establish residence or become citizens of America was recognized at an early date, and laws restricting immigration were placed on the statute books. When undesirable human aliens, legally or otherwise, happened to gain entrance into the United States, such individuals not infrequently were placed safely behind prison bars and then subsequently deported to their native lands; whereas, very little or nothing was done to restrict the movement of undesirable insect aliens or to eradicate the incipient infestation. Thus, the commerce of the United States proceeded almost without restrictions, in so far as plant pests were concerned, until about 50 years ago.

During this long period when our forefathers entertained very little or no fear from insect immigration through human activity, many insect enemies of wild and cultivated crops, domestic animals and man were introduced and a large number of them gained permanent lodgment in our republic. Space and time will not permit the mentioning of even the names of the major insect pests of foreign origin or to discuss the heavy toll exacted year after year, since they have become established, on our plant and animal crops, nor the annual cost of control operations. These few facts regarding exotic insect pests are merely mentioned so that we may pause and reflect for a moment on conditions in the United States reponsible and accountable for the promulgation of federal domestic quarantines, most state plant quarantines, and many state plant pest laws and regulations. In contrast with our insect immigrant problem, it is not a task of long duration to enumerate the federal domestic quarantines and state laws and quarantines based upon native insect pests. It would be interesting to secure the information needed to compare control costs and crop damage of native insect pests with those of introduced species. Perhaps the total monetary cost of control and losses to crops from feeding injury and disease transmission of the two groups would not differ very greatly year after year. If the plant regulatory and quarantine structures of the United States are to be further simplified and coordinated among the states, this one point, however, is very definite and certain—every effort must be made to keep alien pests from entering our country.

The first really serious attempt to prevent undesirable alien plant pests from disembarking on United States soil resulted in Congress passing the Plant Quarantine Act of 1912. In passing, it should be noted that the previous Insect Pest Act of 1905 was very inadequate and failed to meet the demands of the few years it was on the statute books. Since 1912, however, much has been accomplished by the cooperation of federal and state workers. Reports and discussions indicate, I am sorry to say, that there are still a few state and federal officials who would do away with most quarantines and regulations affecting international commerce, even though the known and apparent plant pest risk to our agricultural crops by such actions would be very grave. The latter statement is equally

true relative to some state quarantines and regulations.

As the United States is now taking an active and leading role among nations of the world in the enforcement of regulations and quarantines to prevent further introduction of plant pests by international commerce and transportation, every effort should be made by state officials to aid and support this important field of federal work. The introduction of new foreign insect pests of a serious nature would undoubtedly mean more federal domestic quarantines and, later, more and more state quarantines and regulations. At this point, it seems highly desirable to emphasize that plant regulatory work from both federal and state points of view should go forward without serious interference or letting down during the present national emergency. The means of insect transport and spread by human agencies are increasing by leaps and bounds and are most likely to continue at a similar rate for many years to come. Some authorities estimate that there are more than 20,000 species of insects, many with harmful potentialities, in other lands which have as yet not been introduced into the United States. These staggering figures of foreign pest numbers make us realize more fully than ever the importance of importation inspection, dependable commodity treatment, and the need of regulating international commerce. The regulation of foreign commerce, as in the case of domestic trade between states, should be predicated solely upon the pest risk and sound biologic data and knowledge. Biologic data and knowledge are products of research, and therein lies the only hope of meeting and solving our insect immigrant problem. Emergency work, action programs, and commodity treatments should also have more important places in both state and national research programs, for the answers are often needed almost immediately and must be secured within a very limited period of time. Also, it should be borne in mind that the borders in research, extension and regulatory work frequently overlap and not infrequently dovetail deeply into one another from various angles. Action programs are also not clear cut, and team work and cooperation in the various fields are often necessary.

Authorities of the Council of State Governments estimate that there are more than 3000 trade barriers, of some kind or other, in existence today in the United States. To assemble, classify and tabulate these laws and regulations would be a task of no small proportions. And if all the laws and regulations were carefully charted, it would be impossible for even a person skilled in the magic art of crystal gazing or with the gifted insight of mental clairvoyance to foresee the almost countless number of administrative rulings and administrative interpretations which such laws and regulations would undergo from time to time as appropriate needs may arise during their enforcement to meet ever-changing situations. Not enough attention today is being given to the importance of rules, regulations and interpretations, for these are much more indefinite and often much worse in the end than the laws and quarantines themselves, as interstate trade barriers. County regulations and city ordinances sometimes fit into the same pigeonhole, especially under licenses of some of our large cities; exemptions from complicated business regulations and discriminatory ordinances are extended to local growers, truckers and sellers while almost every possible effort is made to discourage distant or out-of-state growers.

To sift the good ordinances, regulations, laws and quarantines from the bad requires expert knowledge of the plant pests and an understanding of ecological and even social and economic conditions within the borders of the state concerned. Sometimes one hears the statement that certain states, and, occasionally, even counties in a few states, are attempting to free themselves from all outside regulations for the benefit of their own growers, while they themselves are building up high border fences of nuisances, hindrances and other regulations of various kinds designed to impede and discourage out-of-state growers and dealers from doing business within their borders. Such statements or conclusions, of course, are often absurd or even under extreme conditions are frequently only partly true. Consequently, all complaints and requests for modification of laws and regulations of a state or group of states should be studied carefully by an impartial committee, for facts may show that the regulations in question are highly desirable, just, and

not in any sense of the word, trade barriers, as alleged.

A few remarks on the pioneering and foresight of the American Association of Economic Entomologists seem to be in order, for its accomplishments and leadership from the very beginning of plant regulatory work have borne much fruit. The organization of the "Association of Official Horticulture Inspectors" in 1920 represented the first big national stride of the Association in the right direction. The latter is now known as "The Section of Plant Quarantine and Inspection" and was officially affiliated with the Association in 1913. Many papers on various phases of the plant regulatory work have been read at the annual meetings and published in the JOURNAL,

Foreseeing and recognizing the need of setting up more definite machinery (both regional and national in scope) to aid the states in unifying, simplifying and coordinating plant regulatory work affecting interstate trade, the Association, after much serious study, planned and organized the four regional and national plant boards. The first meeting of the National Plant Board was held in Kansas City, Missouri, during the annual holiday meeting of the Association, in 1926. Since then, regular conferences of the national and four regional plant boards have been held every year and, occasionally, interim meetings of a regional or national nature have been called to consider emergency problems. The plant boards have given considerable time and serious study to various phases of state regulatory work in order to bring about more uniformity and to eliminate unnecessary quarantines and regulations. The past achievements and accomplishments of the plant boards are numerous and, with the development of more confidence in the actions and recommendations of the boards, by the officials of the different states, the future possibilities are most encouraging.

Both regional and national plant boards have taken a definite affirmative stand on many problems for the purpose of alleviating many difficulties in the plant quarantine and regulatory structures of the United States. Most states now see the importance of working, pulling and teaming together for the continuous adjustment of external relations to internal relations so as to improve the orderliness of interstate trade. Some of the present criticisms, however, show considerable lack of an understanding of plant regulatory work and are based almost solely on biased opinions rather than actual facts. Most states realize quite fully the importance of all working together with due deference to state rights and with the fact in mind that it is not necessary or desirable for all states to have exactly the same laws and regulations. Total or complete standardization represents one extreme, and lack of simplicity and uniformity the other; neither, of course, is desirable in toto.

Much progress has been made in reducing the multiplicity of regulations of various types by the states in cooperation with the plant boards, yet there remains much more that needs to be done. The principle of free trade and free intercourse of the people in interstate trade is amply supported and widely accepted in all walks of American life; and seems to be the only hope for handling satisfactorily the ever-growing commercial and interlocking trade problems of our vast country.

The trend of individual states to enact legislation and promulgate regulations toward further economic protectionism and economic isolationism by means of trade barriers of one kind or other has been definitely checked, at least for the moment. Many states have responded wholeheartedly to the nationwide call by federal and state officials, growers and other commercial organizations, and to the recommendation of the plant boards for the elimination of unnecessary trade barriers and the need for simplifying and coordinating necessary laws, regulations and quarantines. As a result of the honest efforts of groups of people and organizations of various kinds interested in plant regulatory work, many states have simplified or revoked many unnecessary laws and regulations during the past decade and, in many instances, standardized necessary ones for regions of somewhat similar biotic conditions. And still more encouraging yet is the fact that very few or no new plant regulatory laws have been enacted and put on the statute books of a number of states during the past decade. Most regulatory officials, growers and dealers during this period of changes and trade barrier crusade still recognize the need of just laws and regulations which

are enforced honestly and impartially without favor to any person or organization to prevent the spread of serious insect pests and plant diseases. The true spirit of the present day is for a state to treat outside growers and shippers in exactly the same way as the home state producers. To repeat in simple and plain words, all laws, regulations, quarantines, and administrative rulings and interpretations should always apply equally and impartially under every condition to the growers, producers and sellers within the state limits as well as to those outside its own boundaries.

The increased transportation facilities, speedier, larger and refrigerated boats, trains and trucks, and aircraft transportation have greatly changed the picture today. The greatly increased bulk of world commerce and intercourse of man frequently calls for quick thought and immediate action on the part of state and federal regulatory officials. As we now frequently measure distances in terms of hours or days instead of miles, many countries of both the Eastern and Western Hemisphere lie within one, two or only three days of our shores or borders, and even the most distant nations of the world less than a week from any state by stratisphere transportation. Thus, conditions today make it impossible for any state or group of states to act independently without regard for other states, or to consider themselves isolated from the rest of the world. Cooperation among the states and between the states and federal government is almost infinitely more necessary today than it was a few decades ago. However, cooperation does not provide anywhere near a complete answer to our regulatory structure problems, but getting closer and closer together does contribute very materially to a better and more orderly interstate movement of living plants and plant materials.

Such questions as "Who is to blame?", "What can be done to simplify and coordinate the plant quarantine structure of the United States?", and other similar queries are eternal questions with widely varying answers of five or more dimensions. Although much work needs yet to be done, many difficult problems have hardly been touched and by far the more tedious and difficult tasks lie ahead. In passing, however, the fact should not be overlooked that plant quarantine officials have been working together as individuals and groups or associations for more than 40 years. Much has been accomplished, individually and collectively, during this period; not perfectly, of course, for perfection has not yet been attained on this side of Heaven.

And, after all, new knowledge, new occasions, new demands, national and international crises and adverse stress call for new thought, timely action and leadership that are of the hour and times and more applicable to the future. To accomplish these new ideals and ends, one cannot be an adherent to any particular system or formula, nor to any special or "pet" theory. Changes and improvements in plant regulations, as in other human affairs, come slowly, item by item, and the way is not always very clear nor very easy. Conflicts of one sort or other not infrequently lie in the views of the extremists of all camps. On the whole, and in spite of some differences, state and federal leaderships in plant regulatory work as in other fields of endeavor have been chosen fairly well by the democratic process, otherwise our nation would never have attained its present stature and greatness.

In conclusion, it seems once again desirable to point out and emphasize the fact that the development of simplicity, coordination and cooperation in plant regulatory work begins at home, within the borders of each individual state; then, regional and national unification, collaboration and cooperation will not be so difficult. The development of intra- and interstate confidence in personnel, inspection standards, point of origin certification, elimination of fees, lifting of unnecessary laws and regulations, uniform treatment for "in-state" and "out-state" growers, dealers and sellers, fair and impartial enforcement of regulation, no preferential escapes or exemptions of laws and regulations for local and home growers and numerous other items now being discussed individually and collectively by the state and federal officials during the annual conference of national and regional plant boards. These annual meetings of the plant boards represent mass movements, both regional and nationwide in scope and cooperation, and involve all federal and state officials in plant regulatory work.—1-26-42.

Regulatory Pest Control in California[1]

GEO. E. WOODHAMS, *Agricultural Commissioner, San Bernardino, Calif.*

In addition to the regulatory features of plant and animal quarantine enforcement, California has developed other phases of "Regulatory Pest Control." In reality there are three types of such pest control work in the State.

1. The use of eradicative or control measures against agricultural pests or diseases which have become established some place within our borders. This phase of the problem includes the enforced clean-up of nurseries to prevent the spread of pests from one locality to another. The Agricultural Code also designates that certain serious pests are public nuisances. This provision applies to citrus white fly, camels' thorn, Austrian field Cress and black currants. The code declares it to be unlawful to disseminate weed seeds, and further provides for the establishment of weed-free areas within the state. This is in addition to the abatement of weeds under the provisions to be discussed later. Provision is also made for the extermination of rodents harboring diseases transmissible to humans.

In this field of eradicative pest control work, the law also provides for the establishment of host-free districts and periods when such a procedure is necessary for the control or eradication of serious agricultural pests or diseases which are not widely disseminated throughout the state or locality where they may become established temporarily.

2. A second phase of regulatory pest control to be considered is that of pest abatement work, which is carried on under the legal provisions of the state agricultural code.

Most of our plant pest control work is done voluntarily by the owners of such infected or infested plants or crops. In many instances of plant pests, because of the nature of the pest, the decision as to whether or not treatment is to be given is left to the discretion of the owner of the property. In most cases such pests are not considered to be of a nature subject to quarantine and frequently they are subject to wide fluctuations of population, due to climatic conditions, or biological control by secondary insects. However, there are a number of serious pests, such as scale insects, which require unified community effort, and cooperation, to reduce their ravages.

In some cases, we have growers who refuse, or neglect to treat the pest, poison the rodents or control the weeds on their property. Because of this situation, California has enacted legislation under which we are able to enforce compulsory abatement of the pest involved. These abatement provisions are embodied in the state agricultural code and in addition to this type of regulatory procedure, the code provides that such unabated pests constitute a public nuisance. It is essential for us to have this regulatory pest control system in order to protect those in the community who carry on a careful, well-planned campaign of pest control on their properties.

Under the compulsory pest control procedure the County Agricultural Commissioner, or his deputies and inspectors, serve a legal abatement notice on the owner or person in charge of the infested property and copies of the notice are then served on those holding encumbrances. The pest and time limit for treatment are stated in the notice and if the abatement work is not conducted by the persons served, the commissioner is authorized to do the work. The expense of the compulsory treatment is paid by the county and the charge becomes a lien on the property —similar to that of taxes and property assessments, providing the abatement notice has been recorded. Notice of lien is to be recorded within 30 days after the date of actual payment of the treatment costs. A penalty of 15 per cent is added to the lien if the treatment cost has not been paid within 80 days. Foreclosure is started by the district attorney, representing the county, within 120 days after recording of notice of lien, and then if the bill is not paid the property is sold.

Pests which exist in public parks, along streets and highways, or are subject to the jurisdiction of city, county or state, are also included in the abatement procedure, but definite methods of notifying the governing body as to the existence of

[1] Paper presented at the Meeting of the Section of Plant Quarantine and Inspection, San Francisco,

a serious pest are provided by the code. Pests found on property subject to the control of irrigation, drainage, flood control, reclamation districts, levy districts, or other political subdivisions also come under provisions of the state agricultural code relative to abatement procedure.

In the case of abandoned, or neglected, plants or crops, there is a similar but more complicated procedure in which the superior courts order infested, or infected, plants or crops removed. Liens and disposal of property is provided if the expense of plant removal is not paid within the time limit specified by the code.

3. A third type of regulatory pest control procedure is that in which the state law provides for the establishment of horticultural protection districts. For instance under the provisions of the "Horticultural District Protection Act" we have such a system set up by state law. The purpose of this act is defined as "An act providing for the organization and government of horticultural protection districts for the purpose of protecting horticultural products, and the vines, trees and shrubs whereon the same are grown against diseases, insects and pests; defining the powers of such districts and authorizing any such district to eradicate, remove or prevent the spread of any disease, insect or pest injurious to the horticultural product which such district is organized to protect; to provide for the levying and collection of taxes; to pay the costs and expenses of administering such districts and carrying on their operations; defining the duties and powers of county agricultural commissioners, and other county officers in connection with such districts; to provide for including lands within and excluding lands from any such district, and to provide a method of dissolving such districts."

A second act which is of importance to the California citrus growing districts of the State, is the "Citrous Pest District Control Act," which states "An act providing for the organization and government of citrous pest control districts for the control and eradication of citrous pests, defining the powers of such districts, providing for the levying and collection of taxes to pay the costs and expenses of administering such districts and carrying on their operations, defining the duties and powers of county agricultural commissioners and other county officers in connection with such districts, providing for the inclusion of lands within and the exclusion of lands from such districts, and providing for a method of dissolving the same, declaring the urgency of this act, to take effect immediately."

This type of compulsory pest control work is carried on in San Bernardino County, where I perform the duties of County Agricultural Commissioner. This district work started on a voluntary basis, and membership in the leagues included citrus growers who desired to cooperate in the control of citrus red scale. However, many people refused to join the voluntary district, so the interested growers asked for legislation providing for compulsory membership in the red scale districts. All citrus acreage in the outlined districts is assessed for the work to be done in that particular district. The assessments are collected in a manner similar to the collection of taxes.

In San Bernardino County, we have three different types of procedure followed in the compulsory districts:

1. In Fontana, we have a district in which the assessment money is expended only for the treatment of infestations. The growers and the County Agricultural Inspectors are depended upon to find the infestations and report them to the directors of the district. The entire cost of treatment is paid by the district.

2. In Bloomington the district expends its money only for the inspection of citrus orchards for red scale infestations. The individual grower provides funds for the treatment of the infestation.

3. In the compulsory district which embraces Redlands, Highland, Crafton, Mentone and Bryn Mawr, the district funds are used for Red Scale inspection and treatments. The funds handled by this district are in the neighborhood of $90,000 per year.

These districts each have a board of directors responsible for the formation of policies and the expenditure of the funds allotted for the control work. The directors work without pay.

There are many other phases of regulatory pest control work which cannot be discussed in such a short time; however, it is the purpose of this paper to give some idea of the trends of this type of pest control procedure now being used in

California. We do not depend entirely on the voluntary cooperation of the individual to take care of his pest problems; but the farmer himself, through his legislative representatives, has provided for a legal procedure through which treatments may be required by the agricultural regulatory officers, and it is necessary that results be satisfactory to the enforcing officials.—1-26-42.

Why California Agricultural Commissioners Are State Plant Quarantine Officers[1]

HAROLD J. RYAN

A state plant quarantine officer is the enforcement officer of plant quarantines working under the direction and control of the chief quarantine officer of the state, —according to the California Agricultural Code this state officer is the Director of Agriculture, appointed by the Governor and paid by the state.

The County Agricultural Commissioner is a county officer appointed by the governing body of the county, the Board of Supervisors, and paid by the county. This county officer is however, an enforcing officer of the state quarantine laws, and "as to such activities is under the supervision of the Director."

How this came about is explained by a brief history of California quarantine legislation. We must go back to the California experience with cottony cushion scale beginning in 1872, the grape phylloxera and co lling moth found in California in 1874, and the alarming damage by San Jose scale in 1879.

The viticulturists got going first and secured a state law creating a board of viticultural commissioners in 1880. In 1881 the powers of this board were enlarged to provide for appointment of a Chief Executive Viticultural and Health Officer and a Chief Executive Horticultural and Health Officer. These officers were empowered to do just about anything they considered necessary to prevent the spread and introduction of pests. Matthew Cooke was appointed Chief Executive Horticultural and Health Officer.

In that same year a state law was passed authorizing the County Board of Supervisors of each county to appoint upon petition of twenty-five resident freeholders, a County Board of Horticultural Commissioners, consisting of three members. Many counties at once appointed Boards of Horticulture. These Boards proceeded immediately by inspection and disinfection, by ordinance and regulation, to prohibit, control and extirpate "any insect or insects or the germ thereof."

The ensuing smoke of battle to determine constitutionality of these radical new measures designed to control the business practices of nurserymen and fruitgrowers cleared away enough by 1889 so that at least nineteen of the more important horticultural counties had horticultural boards.

With the passing of the years, the State Board of Viticultural Commissioners became a State Board of Horticulture, then a State Commissioner of Horticulture, and so to the present title of Director of of the State Department of Agriculture.

In 1911 the state law changed the County Board of Horticultural Commissioners to one County Horticultural Commissioner, to be appointed by the Board of Supervisors from an eligible list certified by examination given by a state board of horticultural examiners and authorized the Commissioner to appoint a deputy, also chosen from a list of qualified eligibles certified by the state board of examiners.

This same law authorized the State Commissioner of Horticulture to issue commissions as state quarantine guardians to the County Horticultural Commissioner, his deputy and inspectors. The effective use of the county inspection forces as state quarantine enforcement officers was thus begun thirty years ago.

The statutes of 1921 made the County Horticultural Commissioner ex officio a state quarantine guardian and said "they shall carry out their respective duties—

[1] Paper presented at the Meeting of the Section of Plant Quarantine and Inspection, San Francisco, 1941.

under the direction of the Director of Agriculture."

The state law of 1923 required that inspectors appointed by the County Horticultural Commissioner must be from an eligible list certified after examination by the Director of Agriculture.

This provided a set of laws and machinery essentially as it exists today, with the title of the county officer changed to County Agricultural Commissioner and the state quarantine laws codified in the California Agricultural Code.

Fifty of the fifty-eight California counties have County Agricultural Commissioners. Some counties have their own Civil Service laws, but certificates of eligibility for appointment of commissioners, deputies, and inspectors must come from the Director of Agriculture who conducts examinations in non-civil service counties and cooperates with examiners in Civil Service counties.

The Director of Agriculture is the chief enforcement officer of the state with his force of state Civil Service employees doing quarantine work at state and maritime ports. The County Agricultural Commissioners, deputies, and inspectors, are state enforcement officers at interior points under the supervision of the chief state officer. 1-26-42

California Intercounty Inspection Problems

GORDON B. LAING,[1] *Alameda, California*

The inspection problems arising from the movement of plants and other pest carrying materials between counties in California are in all respects quite similar to interstate problems with the exception of a difference in size of the geographical areas involved. For the purpose of review, it is my opinion that the problems of intercounty inspection can be placed in two main categories. The first category embraces those problems which arise from the variations in the uniform application of inspection procedure and the second embraces those problems which are encountered in the evaluation of the status of the pest involved.

In considering the problems arising from variations in inspection procedure, it has been found from experience that variations within limits are sometimes necessary. Inspections of host material moving between counties may vary considerably in severity directly in relation to the serious character of the pest involved as well as to the pest condition of the county to which such material is destined. Quarantine inspection must be geared to the pest with which we are dealing and should at all times be adequate to protect the value of either pest control or eradication programs operating in the respective counties. To one not familiar with local conditions, this situation may have the appearance of lack of uniformity in inspection procedure. In reality such procedure is designed to adequately deal with pest conditions of the respective areas involved yet at the same time permit the movement of commercially clean host material, which itself may carry light infestations of established pests, into other areas where the pest under consideration may be generally present or of no economic importance because of the absence of economic host material. As for example, *Chrysomphalus Aurantii*, red scale, is either not known to occur or is under a very intensive eradication campaign in certain citrus producing counties such as Ventura and Santa Barbara. Naturally in order to give adequate protection to the citrus industry of this area, host plants of the red scale are subjected to a much more rigorous inspection program than are the same plants destined to a point, say, in Los Angeles County. Los Angeles County, because of the general distribution of red scale therein must be content with control programs and an inspection procedure less rigorous than that of Ventura County.

The uniform application of inspection procedure presents a problem when adjoining counties have divergent agricultural interests which in turn may serve to prevent employment of adequate inspection forces to protect the area which may

[1] Agricultural Commissioner for Alameda County.

be a geographical entity. Pests introduced into one county will not regard the invisible county line but will proceed to spread naturally to all areas where host plants exist. To solve this problem communities of interest between adjoining counties have been built up in recent years through the supervision and guidance of our Bureau of Entomology and Plant Quarantine of the California Department of Agriculture.

Effective inspection procedure involves the use of a great number of men specially trained as inspectors who act in accordance with sound plant quarantine principles. Personal opinions of inspectors may, if permitted, interfere seriously with the efficacy of plant inspection. The problem then is always present of requiring the inspector to correlate his opinions with scientific data and experience in order that material may be disposed of properly and uniformly.

New and rapid methods of transportation and merchandising of plants and plant material present what is probably the greatest hindrance of all to proper and uniform inspection procedure. Shipments of pest host material move in large volume by truck and automobile from one area to another and with such rapidity that it has become increasingly difficult to devise means to intercept and inspect such shipments. Adequate inspection, treatment and certification at point of origin is an alternate procedure to that of destination inspection which is at present being given serious consideration to cope with the problem of rapid and promiscuous transfer of plant material from one county to another.

The second category of inspection problems which I have mentioned has to do with the improper valuation of the status of the pests encountered. It is my opinion that inspection can be made a mockery and a failure if inspectors do not act in accordance with all available knowledge and experience in judging the importance and correct status of plant pests. Failure on the part of the inspector to recognize the seriousness of a major pest cannot be tolerated by those who have the welfare of plant inspection at heart. It is also evident that the rejection of valuable plant material because of the presence of a pest of minor importance may cause serious resistance to or outright evasion of plant inspection. A most important problem encountered in the inspection of nursery stock and plant material moving between counties then is the one of determining the correct status of the pest encountered. The status of many pests, of course, can be readily fixed by a correct knowledge of scientific data, but there are other numbers of pests which are not quite so easy to evaluate.

The problem of the inspector then is to determine whether or not the pest may cause serious damage or economic loss, whether it has a wide host range, whether it is difficult and expensive to control and whether it is resistant to prevailing climatic conditions. Or on the other hand, is it known that the pest in question would cause little or no damage, or is it restricted to plants of little or no value, or is the pest of common occurrence in the area of destination and can it be easily controlled? A true analysis of all these and other factors must be made by the inspection authority if the true status of a major or minor pest is to be determined.

SUMMARY.—Intercounty inspection problems in California may be grouped into two main groups. The first group embraces those problems arising from the required and necessary uniform application of inspection procedure by a large number of inspectors. A variation from uniform procedure may be justified by an analysis of the pest conditions prevailing in the areas involved and in order to cope with new problems such as those presented by the rapid transportation of plant material by truck and private automobile, it may be necessary to revise accepted procedure to prevent the movement of injurious pests. The second major group embraces those problems involved in the determination of the true status of the pests encountered during inspection operations. The use of all data available and a knowledge of all factors involved should enable the inspector to decide whether a pest is of major or minor importance.—1-26-42.

SCIENTIFIC NOTES

Control of Flea Beetles on Potatoes at New Church, Virginia, in 1941[1]

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Potato spray tests were made this season at New Church, Virginia for the purpose of comparing the effectiveness of several rotenone bearing mixtures and new copper compounds with a calcium arsenate-bordeaux, 4-8-12-100 spray for the control of the potato flea beetle, *Epitrix cucumeris* Harris.

In this experiment 8 treatments were tested on four row plats, 270 feet long, replicated 3 times. Applications were made with a 4-row, 3 nozzle to the row, engine-power sprayer that maintained a pressure of about 250 pounds. The materials,[2] the proportions at which they were used, the time and number of applications, and the results obtained are given in table 1.

The overwintering brood of flea beetles was quite abundant this year causing considerable foliage injury on the young potato plants early in the season. The first spray application was made on May 22 and by the time of the second application on May 31 most of the beetles had disappeared. At the time the new brood of beetles usually appear, between June 15 and 20, there were very few present and it was thought that the unusually hot dry weather prevailing at that time might have destroyed most of them. However, such was not the case for by June 27 the beetles of the new brood were very abundant and all unsprayed and poorly sprayed potato foliage was severely injured. The bordeaux and *Copper Hydro* treated plats were greatly benefited by rains that temporarily broke the hot dry spell on July 3, 4, and 5 whereas the other plats were so nearly defoliated at this time that they received practically no benefits from these rains.

Within 7 to 10 days after the last treatment the insecticides began losing their effectiveness in flea

[1] Eastern Branch Program, Baltimore, 1941.

[2] The calcium arsenate used in this test is 70% tri-calcium arsenate and 30% inert ingredients with less than .75% water soluble arsenic (metallic). *Syntone*, supplied by the U. S. Rubber Co., New York, N. Y., is a concentrated activated rotenone emulsion containing a stabilizer and is 2.8% rotenone, 5.2% other derris resins, 32.0% insecticidal oil (alkaylted hydrocarbon derivative), and 60.0% inert ingredients. The yellow cuprous oxide was *Yellow Cuprocide* (83% copper) and was furnished by Rohm & Haas Co., Philadelphia, Pa. *Calgreen* and *Copper Hydro* were furnished by Chipman Chemical Co., Bound Brook, N. J. *Calgreen* is an air-floating paris green wet-blended and reacted with calcium arsenate and it contains not less than 7.00% cuprous arsenite, not less than 64.43% tri-calcium arsenate, not more than 1.00% water soluble arsenic (metallic), and not less than 28.57% inert ingredients. *Copper Hydro* is a neutral copper fungicide containing not less than 26% metallic copper and not more than 74% inert ingredients. "*Grasselli*" *Spreader-Sticker* contains sodium oleyl sulfate as the spreader and a synthetic plastic as the sticker and was supplied by E. I. du Pont de Nemours & Company, Wilmington, Del.

Table 1.—Results of testing different spray materials on potatoes at New Church, Virginia, in 1941

Materials Used[2]	Applications[3]	Leafhopper Nymphs on 15 Leaves June 24	Flea Beetle Injury, Holes Per Sq. In. of Leaf Surface		Yield, U. S. No. 1 Potatoes, Per Acre	Increase Over Check
			July 24	July 3		
Calcium arsenate—bordeaux	All 5	4	13.5	20.9	203	75%
Calcium arsenate—bordeaux *Syntone*—bordeaux	1-2-3 4[1]-5[1]	4	14.2	27.0	193	67
Calcium arsenate—bordeaux *Syntone*—bordeaux	2-3 1[1]-4[1]-5[1]	4	16.9	25.9	185	60
Calcium arsenate—bordeaux Derris—bordeaux	2-3 1[1]-4-5	3	18.2	23.0	178	54
Calgreen— *Copper Hydro*	All 5	27	34.1	49.2	175	51
Calcium arsenate—talc yellow cuprous oxide	All 5 1[1]	13	44.1	80.0	149	28
Derris—talc yellow cuprous oxide	1[1]-3-4-5	67	51.8	117.8	138	19
Untreated check	—	134	65.2	528.0	116	—
Difference necessary to be significant		60	12.5	14.2	14.7	—

[1] *Grasselli spreader-sticker* used in these applications at the rate of 1/1600.

[2] Calcium arsenate, *Calgreen* and derris (5% rotenone) were used at the rate of 2 pounds to 100 gallons; bordeaux, 8-12-100; *Copper Hydro*, 5-100; Talc, 5-100; yellow cuprous oxide, 1.5-100; *Syntone*, 1 to 300 by volume in the May 22 application, and 1 to 200 in all other applications.

[3] Applications made May 22 31, June 11, 19, and 27, are refered to as 1-2-3-4-5 respectively.

beetle control and by the time the potatoes were dug on July 22, practically all of the plants were dead in all plats. Yield records were obtained by harvesting 250 feet of the two middle rows of each plat.

Flea beetle foliage injury records were obtained by counting the number of feeding scars in a 0.568 square inch sample cut from the center of each of 75 leaflets selected at random from each treatment.

In this test as in the potato spray tests conducted in this area during the past 9 seasons (Anderson & Walker, 1940), the calcium arsenate-bordeaux spray treatment gave the best results. During the 10 year period this treatment has resulted in an average increase in yield of 38 per cent, or 69 bushels of prime potatoes per acre.

Derris and *Syntone* in combination with bordeaux gave a high initial kill of the potato flea beetles and the foliage treated with these materials was relatively free from flea beetle injury. However, for some unknown reason, when these materials were substituted in place of calcium arsenate in the bordeaux spray at the time of the greatest flea beetle abundance, they resulted in a lower yield. No spray injury to the foliage was observed in any of the plats in the entire experiment. Fulton & Nelson (1941) show that rotenone bearing materials are more compatible with bordeaux than has been believed.

It may be noted that the plants sprayed with the best yellow cuprous oxide mixture had nearly five times as many flea beetle feeding scars on the leaves and produced 54 bushels less of prime potatoes than did those receiving the regular calcium arsenate-bordeaux treatment. The yellow cuprous oxide treated plants lost their foliage nearly as quickly as did the untreated check plants, which was from 2 to 3 weeks prior to the loss of foliage on the Bordeaux treated plants.

Although the *Calgreen-Copper Hydro* treated plants retained their foliage nearly as long as did the bordeaux treated plants they had a little over twice as much flea beetle foliage injury and yielded 28 bushels less of prime potatoes than did the bordeaux treated plants.

RESISTANT VARIETIES—In flea beetle resistant potato varietal tests made at New Church, Virginia during the spring seasons of 1940 and 1941, it was found that the foliage of the later maturing Sebago and Sequoia varieties had significantly less flea beetle feeding scars per square inch of leaf surface than did the foliage of the early maturing Cobbler variety. Also that the Sebago and the Sequoia gave about the same yield which was significantly more than the Cobbler when all of the varieties were allowed to completely mature. However, the Cobbler produced as high or higher yields than did the Sebago and Sequoia when the plants were dug at the time of or prior to the complete maturity of the Cobbler.

CONCLUSIONS—In conclusion it may be stated that as indicated by these tests, the substitution of rotenone bearing materials for calcium arsenate in a bordeaux spray mixture on potatoes in this area is not desirable.

Also potato plants sprayed with calcium arsenate-bordeaux (4-8-12-100) mixture have sustained less potato flea beetle injury and produced greater yields than have any other treated or untreated plants in tests at New Church, Virginia during the past 10 seasons.

Preliminary tests with flea beetle resistant potato varieties indicate that Sequoia and Sebago varieties seem to be more resistant to flea beetle attack than the Cobbler. However, because of their later maturity, it is not advisable to recommend them for spring planting for the early market in flea beetle infested areas without further tests.—11-26-41.

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Toxicity of Certain Acid Amides and Their N-Substituted Derivatives to Codling Moth Larvae

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For several years one phase of the work of the Bureau of Entomology and Plant Quarantine has been the preparation of synthetic organic compounds and their insecticidal evaluation for the purpose of developing new materials that would be toxic to insects and yet relatively nontoxic to warm-blooded animals.

Some N-substituted acid amides have previously been tested for toxicity to insects (Fink *et al.* 1938; McAllister and Van Leeuwen 1930; Siegler *et al.* 1939). The toxicity of compounds of this type to the larva of the codling moth *Carpocapsa pomonella* (L.) was not sufficient to warrant further investigation, but unpublished results obtained by other entomologists of this Bureau on testing against other insects, together with the granting of several patents covering the use of certain substituted acid amides as insecticides, indicated that a further study should be made of this class of compounds.

A study was therefore undertaken to determine whether the toxicity of acid amides to the codling moth larva could be enhanced by the substitution of various hydrocarbon radicals in the N position.

The acid amides were prepared in the usual manner, which consisted in reacting the acid chloride or the ethyl ester with ammonia. The substituted acid amides were prepared by reacting the amine directly with the acid, the acid anhydride, or the acid chloride.

The codling moth larva was used as the test insect in connection with the apple-plug method. A single codling moth egg, in the advanced black-spot stage, was enclosed with each apple plug. The plugs were sprayed as they were carried on a traveling belt beneath the spray nozzle. Two applications were generally made, the first being allowed to dry before the second was given. The compounds were tested at a concentration of 4 pounds per 100 gallons of a carrier which usually consisted of water 80 per cent plus ethanol (95 per cent) 20 per cent by volume.

The results are given in table 1. The most toxic compound was N-2-naphthylformamide, which permitted 56 per cent of wormy plugs. Comparative data for apple plugs treated with lead arsenate showed 19 per cent of wormy plugs. Even this compound is therefore much less effective than lead arsenate. Untreated checks were found to be 93 per cent wormy.

Table 1.—Results of laboratory tests of certain acid amides and N-substituted acid amides against the codling moth larva.

Spray Material	Meaning of R′	Apple Plugs		
		Total	Wormy	Stung
		Number	Per Cent	Per Cent
Formamide and N-substituted formamides $H-\overset{O}{\overset{\|\|}{C}}-\overset{H}{\overset{\|}{N}}-R'$				
Formamide	H	102	89	0
N-Benzylformamide	$-CH_2C_6H_5$	96	93	3
N-Cyclohexylformamide	$-C_6H_{11}$	108	91	2
Formanilide	$-C_6H_5$	105	90	1
o-Formotoluide	$-C_6H_4CH_3$	105	92	1
m-Formotoluide	$-C_6H_4CH_3$	102	89	1
p-Formotoluide	$-C_6H_4CH_3$	99	88	0
N-(2,4-Xylyl)-formamide	$-C_6H_3(CH_3)_2$	100	66	0
N-(2,5-Xylyl)-formamide	$-C_6H_3(CH_3)_2$	91	91	0
N-(2,6-Xylyl)-formamide	$-C_6H_3(CH_3)_2$	102	86	0
N-Xenylformamide	$-C_6H_4C_6H_5$	102	74	2
N-1-Naphthylformamide	$-C_{10}H_7$	100	83	0
N-2-Naphthylformamide	$-C_{10}H_7$	106	56	0
N-2-Fluorylformamide	$-C_{13}H_9$	103	83	2
Acetamide and N-substituted acetamides $CH_3-\overset{O}{\overset{\|\|}{C}}-\overset{H}{\overset{\|}{N}}-R'$				
Acetamide	H	99	86	5
N-Benzylacetamide	$-CH_2C_6H_5$	101	85	2
N-Cyclohexylacetamide[1]	$-C_6H_{11}$	21	95	0
Acetanilide	$-C_6H_5$	107	90	0
o-Acetotoluide	$-C_6H_4CH_3$	101	83	0
m-Acetotoluide	$-C_6H_4CH_3$	107	90	2
p-Acetotoluide	$-C_6H_4CH_3$	104	90	0
N-(2,4-Xylyl)-acetamide	$-C_6H_3(CH_3)_2$	104	94	0
N-(2,5-Xylyl)-acetamide	$-C_6H_3(CH_3)_2$	104	87	0
N-(2,6-Xylyl)-acetamide	$-C_6H_3(CH_3)_2$	101	80	4
N-Xenylacetamide[1]	$-C_6H_4C_6H_5$	97	77	0
N-1-Naphthylacetamide	$-C_{10}H_7$	105	78	1
N-2-Naphthylacetamide	$-C_{10}H_7$	103	80	1
N-2-Fluorylacetamide	$-C_{13}H_9$	102	80	4
Propionamide and N-substituted propionamides $CH_3CH_2-\overset{O}{\overset{\|\|}{C}}-\overset{H}{\overset{\|}{N}}-R'$				
Propionamide	H	98	89	1
N-Benzylpropionamide	$-CH_2C_6H_5$	106	91	1
N-Cyclohexylpropionamide	$-C_6H_{11}$	101	100	0
Propionanilide	$-C_6H_5$	101	77	1
o-Propionotoluide	$-C_6H_4CH_3$	105	80	1
m-Propionotoluide	$-C_6H_4CH_3$	102	92	0
p-Propionotoluide	$-C_6H_4CH_3$	99	82	1
N-(2,4-Xylyl)-propionamide	$-C_6H_3(CH_3)_2$	106	90	0
N-(2,6-Xylyl)-propionamide	$-C_6H_3(CH_3)_2$	103	83	1
N-Xenylpropionamide	$-C_6H_4C_6H_5$	102	77	0
N-1-Naphthylpropionamide	$-C_{10}H_7$	94	84	0
N-2-Naphthylpropionamide	$-C_{10}H_7$	108	89	2
N-2-Fluorylpropionamide	$-C_{13}H_9$	102	75	1
Lauramide and N-substituted lauramides $CH_3(CH_2)_9CH_2\overset{O}{\overset{\|\|}{C}}-\overset{H}{\overset{\|}{N}}-R'$				
Lauramide	H	103	87	1
N-Benzyllauramide	$-CH_2C_6H_5$	95	88	0

SPRAY MATERIAL	MEANING OF R′	APPLE PLUGS		
		Total	Wormy	Stung
		Number	Per Cent	Per Cent
Lauramide and N-substituted lauramides				
N-Cyclohexyllauramide	—C_6H_{11}	105	100	0
Lauranilide	—C_6H_5	105	83	1
o-Laurotoluide	—$C_6H_4CH_3$	103	88	0
m-Laurotoluide	—$C_6H_4CH_3$	94	87	0
p-Laurotoluide	—$C_6H_4CH_3$	99	93	1
N-1-Naphthyllauramide	—$C_{10}H_7$	102	74	3
N-2-Naphthyllauramide	—$C_{10}H_7$	99	87	0
N-2-Fluoryllauramide	—$C_{13}H_9$	98	90	0
Palmitamide and N-substituted palmitamides $CH_3(CH_2)_{13}CH_2—\overset{O}{\overset{\|}{C}}—\overset{H}{\overset{\|}{N}}—R'$				
Palmitamide	H	108	79	0
N-Benzylpalmitamide	—$CH_2C_6H_5$	96	85	0
N-Cyclohexylpalmitamide	—C_6H_{11}	103	98	0
Palmitanilide	—C_6H_5	100	81	1
o-Palmitotoluide	—$C_6H_4CH_3$	104	84	1
m-Palmitotoluide	—$C_6H_4CH_3$	100	80	1
p-Palmitotoluide	—$C_6H_4CH_3$	105	91	1
N-1-Naphthylpalmitamide	—$C_{10}H_7$	108	76	0
N-2-Naphthylpalmitamide	—$C_{10}H_7$	96	88	0
N-2-Fluorylpalmitamide	—$C_{13}H_9$	109	90	0
Benzamide and N-substituted benzamides $C_6H_5C(=O)—\overset{H}{\overset{\|}{N}}—R'$				
Benzamide	H	104	88	1
N-Benzylbenzamide	—$CH_2C_6H_5$	105	96	0
N-Cyclohexylbenzamide	—C_6H_{11}	49	74	0
Benzanilide	—C_6H_5	101	88	7
o-Benzotoluide	—$C_6H_4CH_3$	107	97	0
m-Benzotoluide	—$C_6H_4CH_3$	106	95	0
p-Benzotoluide	—$C_6H_4CH_3$	103	95	5
N-(2,4-Xylyl)-benzamide	—$C_6H_3(CH_3)_2$	99	93	0
N-(2,5-Xylyl)-benzamide	—$C_6H_3(CH_3)_2$	101	92	1
N-(2,6-Xylyl)-benzamide	—$C_6H_3(CH_3)_2$	104	89	0
N-Xenylbenzamide	—$C_6H_4C_6H_5$	103	83	1
N-1-Naphthylbenzamide	—$C_{10}H_7$	105	92	3
N-2-Naphthylbenzamide	—$C_{10}H_7$	109	94	1
N-2-Fluorylbenzamide	—$C_{13}H_9$	108	99	0
2-Furamide and N-substituted 2-furamides $(C_4H_3O)—\overset{O}{\overset{\|}{C}}—\overset{H}{\overset{\|}{N}}—R'$				
2-Furamide (pyromucamide)[2,3]	H	95	75	2
N-Benzyl-2-furamide	—$CH_2C_6H_5$	103	99	1
N-Cyclohexyl-2-furamide	—C_6H_{11}	100	90	0
2-Furanilide	—C_6H_5	100	99	0
N-o-Tolyl-2-furamide	—$C_6H_4CH_3$	103	97	0
N-m-Tolyl-2-furamide	—$C_6H_4CH_3$	104	98	0
N-p-Tolyl-2-furamide	—$C_6H_4CH_3$	95	79	4
N-(2,4-Xylyl)-2-furamide	—$C_6H_3(CH_3)_2$	105	74	0
N-(2,5-Xylyl)-2-furamide	—$C_6H_3(CH_3)_2$	106	78	0
N-(2,6-Xylyl)-2-furamide	—$C_6H_3(CH_3)_2$	107	65	0
N-Xenyl-2-furamide	—$C_6H_4C_6H_5$	104	83	0
N-1-Naphthyl-2-furamide	—$C_{10}H_7$	105	97	0
N-2-Naphthyl-2-furamide	—$C_{10}H_7$	100	90	1
N-2-Fluoryl-2-furamide	—$C_{13}H_9$	100	93	0

[1] Carrier, water.
[2] Bentonite, 4 pounds to 100 gallons, was added.
[3] One application.

From the data we conclude that none of the compounds show promise against the codling moth larva.—4-10-42.

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Toxicity of Sulfanilimide and Related Compounds to the Codling Moth Larvae

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The discovery that sulfanilamide (p-aminobenzenesulfonamide) is effective in the control of numerous bacterial infections has led to the preparation and testing of many related compounds for their therapeutic properties. The ease with which this class of compounds may be prepared and the ready availability of the starting materials made it worth while to evaluate some of them for their possible insecticidal properties.

Table 1.—Toxicity of sulfonamides to the codling moth larva.

Compound	Percentage of Apple Plugs	
	Wormy	Stung
p-Bromobenzenesulfonamide	45	13
p-Chlorobenzenesulfonamide	61	1
Sulfanilamide (p-Aminobenzenesulfonamide)	67	1
7-Acetamido-1-hydroxy-2-(p-sulfamylphenylazo)-naphthalene-3,6-disulfonic acid, disodium salt (Prontosil soluble)	73	0
N^4-Acetylsulfanilanilide	75	2
N-Phenyl-2-naphthalenesulfonamide	78	3
m-Nitrobenzenesulfonamide	79	2
4-(p-Acetamidophenylsulfonyl) morpholine	81	0
2-Nitro-p-toluenesulfonamide	81	0
N, N-Diethyl-2-naphthalenesulfonamide	82	1
p-Bromo-N-1-naphthylbenzenesulfonamide	83	0
N-Methyl-N-p-tolyl-p-toluenesulfonamide	84	0
p-Bromo-N-methyl-N-phenylbenzenesulfonamide	84	0
4-(p-Tollsulfonyl) morpholine	85	0
Dichloramine-T (N, N-Dichloro-p-toluenesulfonamide)	87	1
N-n-Butyl-p-toluenesulfonamide	87	1
2-Naphthalenesulfonamide	87	1
N-1-Naphthyl-m-nitrobenzenesulfonamide	87	1
3-Nitro-N-phenyl-p-toluenesulfonamide	87	1
4-(3-Nitro-p-tolylsulfonyl) morpholine	89	0
p-Toluenesulfonamide	89	0
N, N-Dimethyl-p-toluenesulfonamide	90	0
N^4-Acetyl-4^1-nitrosulfanilanilide	90	0
N-p-Tolyl-p-toluenesulfonamide	91	0
N^4-Acetyl-N^1-o-nitrophenylsulfanilamide	91	0
Chloramine-T (N-Chloro-p-toluenesulfonamide, sodium derivative)	91	0
N^4-Benzylsulfanilamide	91	0
N-1-Naphthyl-3-nitro-p-toluenesulfonamide	91	0
4-Bromobenzenesulfonanilide	92	0
N-Methyl-p-toluenesulfonamide	92	0
N^4-Acetyl-N^1-m-nitrophenylsulfanilamide	93	1
N-Ethyl-p-toluenesulfonamide	94	1
N-Methyl-p-toluenesulfonanilide	94	0
p-Bromo-N, N-dibenzylbenzenesulfonamide	95	0
m-Nitro-N-phenylbenzenesulfonamide	95	1
Sulfanilanilide	95	0
p-Toluenesulfonanilide	96	0
4-(p-Bromophenylsulfonyl) morpholine	97	0
N^4-Acetyl-N^1-1-naphthylsulfanilamide	98	0
p-Sulfamylacetanilide	99	1

The compounds listed in table 1 were tested in the laboratory against the codling moth larva *Carpocapsa pomonella* (L.) by the apple-plug method (Siegler & Munger 1933, Siegler *et al.* 1934). About 100 plugs were used in each test and each plug was infested with a single larva. All compounds were used at a dosage of 4 pounds to 100 gallons of the carrier (95 per cent ethanol 20 per cent plus water 80 per cent by volume). The same carrier, in an amount equal to 20 per cent by volume of the carrier, was added in order to wet the compounds thoroughly. Many of the compounds are soluble in ethanol and were precipitated in a finely divided form when water was added to bring the carrier to the desired volume.

Sulfanilamide gave 67 per cent of wormy apple plugs, and the derivatives, with the exception of p-bromo- and p-chlorobenzenesulfonamide, were less toxic to the larvae. The results with the para-halogen benzenesulfonamides do not, however, appear of sufficient promise to warrant further studies against the codling moth. These conclusions are based on comparative data obtained from 1,766 plugs sprayed with lead arsenate, 25 per cent of which were wormy and 20 per cent were stung. In a series of 1,768 apple plugs that were sprayed with the ethanol carrier for check tests 93 per cent of the plugs were wormy and none were stung.—8-1-42.

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The Present Status of *Parlatoria chinensis* Marlatt in St. Louis[1]

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Parlatoria chinensis Marlatt, a scale insect, was collected from an althea shrub on April 12, 1940 in St. Louis, Missouri. Because this scale was not recognized, it was immediately sent to the Bureau of Entomology and Plant Quarantine, Washington, D. C. for identification. As soon as our Department was informed of this pest, steps were taken to determine the extent of the insect in the vicinity where it was collected. A hasty examination of plants on nearby properties disclosed that a local infestation existed in south St. Louis. This was followed by a preliminary survey during the early summer to approximate the area infested. Other regulatory work did not permit us adequately to complete this survey.

Aid was requested from the Bureau of Entomology and Plant Quarantine in the fall of 1940 by the State Department of Agriculture. The Bureau responded by providing eight entomologists to assist in the fall

[1] Presented before the Section of Plant Quarantine and Inspection, San Francisco, 1941.

survey during the dormant season. This survey revealed that approximately 109 city blocks, Tower Grove Park, the Missouri Botanical Garden and a small portion of Forest Park were infested with *Parlatoria chinensis*. The scale infestations were heaviest in the vicinity of the Missouri Botanical Garden and Tower Grove Park.

From this general area the infestation became lighter in all directions but extended itself farther to the east, north and northwest. This extension may be influenced by several factors such as more favorable host plants, prevailing southerly winds during the summer and the flight of many birds between Tower Grove Park and Forest Park areas.

After the *Parlatoria chinensis* infested area was delimited, a quarantine was established and descriptive copies thereof were delivered door to door to every home, apartment house and business address within the area involved. The State Department of Agriculture has put forth a continuous effort to enforce these quarantine restrictions.

Various dormant oils of known merit when used on other scales, were used on *Parlatoria chinensis* in an effort to find a control which would supplement a proposed eradication program. A satisfactory control was not obtained from the dormant oils. Various summer oils were used later and at the time they showed more promise of control but are still on the doubtful side. This work, as well as life history studies, is being conducted cooperately by the State Department of Agriculture, the Federal Bureau, Division of Fruit Insect Investigations and the Missouri Agricultural Experiment Station.

At the present time, there is not sufficient definite information available to give a complete life history report of *Parlatoria chinensis*. Studies during this past year indicate that the scale winters as a fertilized adult female. The female deposits eggs in May or June depending on the temperature. Crawlers hatch out in approximately ten days and require about six weeks to reach the adult stage. The second brood appeared about July 15. A partial third generation was observed this year as late as Nov. 1. When these studies have been completed, a report will doubtless be published by one of the cooperating agencies.

Further investigations are being conducted this fall in the hope of finding a satisfactory dormant oil spray. Other experiments relative to tent and box fumigation treatments are being conducted in St. Louis by the Federal Bureau, Division of Control Investigations.

An intensive survey has been in progress since November 10 and is scheduled for completion about February 1, 1942, if weather permits. Participating in this survey are eight entomologists from the Bureau of Entomology and Plant Quarantine, three from the Missouri Agricultural Experiment Station and five from the Missouri Department of Agriculture. The purpose of the survey is to determine the build-up of the scale within the known infested area and the extent of spread of previously uninfested areas.

Results of this survey to date indicate a very definite increase over the infestation as reported a year ago. Some properties previously reported as being lightly infested are now found to have host plants heavily encrusted. In addition, approximately 30 city blocks have been brought into the infested area as of December 20. Following the completion of the survey, the present quarantine boundaries will be extended to include the additional areas. Most of the newly infested blocks include only one or two properties with a very light scale population. The number of host plants involved includes approximately 42 genera and more than 85 species with five of these genera being added this winter. We cannot point to any one genus or species as being a favorite host plant. However, observations indicate that apple, peach, pear, cherry, althea, lilac, privet, currant, viburnum, cotoneaster, and buckthorn are among the plants most commonly found to be infested.

Our Department proposes a limited eradication program, the first objective of which will be the removal of infested plants from the marginal properties surrounding the major area of infestation. Supplementing the removal program, we propose to apply dormant or summer oils which may be indicated by the results of the present control investigations. As funds are made available to the State and Federal Departments of Agriculture, additional surveys, removals and treatments are to be undertaken with a view to continued suppression and ultimate eradication.—1-26-42.

A Continuation of the Studies of the Relative Effects on Insect Metabolism of Temperature Derived from Constant and Varied Sources[1,2]

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The present paper stems back to one published in 1940 (Headlee 1940) in which the writer said: "It appears, therefore, that the relation of the metabolic effect of variable temperature and constant temperature is dependent upon where, in the temperature gamut of the particular insect or stage concerned this variable and this constant lie. The next step in an investigation of this sort is to accumulate data in the hope of working out a reliable ratio." This paper sets forth data showing these ratios for a mosquito known as *Aedes aegypti*.

For the purpose of showing the basis on which the succeeding studies were made the sigmoid curve of temperature reaction for *Aedes aegypti* is set forth

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station. Rutgers University, Department of Entomology.
[2] Eastern Branch Program, Baltimore, 1941.

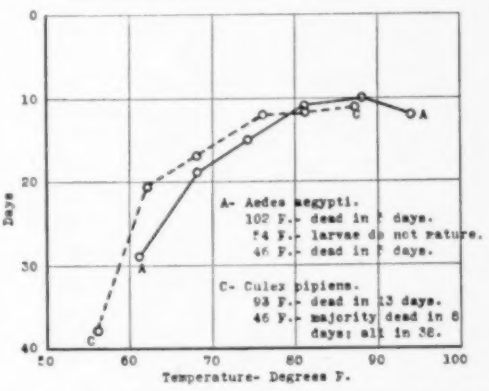

FIG. 1.—Development of mosquitoes as affected by temperature conditions.

Table 1.—Relation of metabolic power of variable and constant temperatures in the different sections of the sigmoid curve.

Section of the Sigmoid Curve	Days Required to Complete Development from Newly Hatched to Adult		Ratio[1] to Metabolic Power of Variable to Constant	Percentage Emerging	
	Variable	Constant		Variable	Constant
Top section Variable = 81°F.–91°F. Constant = 86°F.	10.5	10.5	1:1	77	69
Straight-line section Variable = 68°F.–81°F. Constant = 74.5°F.	13.0	14.5	1:0.89	89	83
Bottom section Variable = 61°F.–71°F. Constant = 66°F.	22.0	22.5	1:0.97	91	90
Sub-bottom section Variable = 58°F.–68°F. Constant = 63°F.	32.0	30.5	1:1.05	77	79
Sub-sub-bottom section Variable = 55°F.–60°F. Constant = 60°F.	55.0	38.5	1:1.42	15	32

[1] The greater the metabolic power of temperature the shorter the period required to complete growth. Hence, when the variable is taken as unity, the variable in terms of days required to complete divided by the constant in days required to complete gives the ratio of metabolic power of variable metabolic power of constant.

in figure 1. For comparative purposes the recently completed sigmoid curve of temperature reaction for *Culex pipiens* is placed in the same figure. Each temperature datum point in the sigmoid curve represents the reaction of a minimum of 100 mosquitoes.

It is perhaps interesting to know that *Aedes aegypti*, a tropical and sub-tropical mosquito, succeeds in attaining full development in a temperature around 60°F. while *Culex pipiens*, a temperate zone mosquito succeeds in making full development at as low as 56°F. On the other hand, *Aedes aegypti* succeeds in making full development in temperatures as high as 94°F. while *Culex pipiens* succeeds in making full development at a temperature of 87°F. This, of course, is just about such a difference as one would anticipate finding between a tropical and sub-tropical mosquito and a temperate zone mosquito.

In the tests recorded in table 1 the minimum number of individual mosquitoes included in the variable temperature of any run is 100 and likewise the minimum number of mosquitoes employed in any constant temperature run is 100. It is felt that when the number of mosquitoes maturing reaches in the neighborhood of 80 per cent of the total number with which the experiment is begun, the results are likely to be very reliable and that reliability will decrease as the percentage maturing decreases.

Determinations of the relative effects of variable and constant temperatures where the constant is run at the exact average of the variable have been made for the top section, the straight-line section, the bottom section, the sub-bottom section and the sub-sub-bottom section of the sigmoid curve for *Aedes aegypti*. The results are set forth in table 1. This table presents data on days required to complete development from newly hatched to adult, the ratio of metabolic power of variable to constant, and percentage emerging.

Briefly stating the results of this study, the top section shows the ratio of variable to constant as 1 is to 1, the straight-line section shows the relation of variable to constant as 1 is to 0.89, the bottom section shows the relation of variable to constant as 1 is to 0.97, practically as 1 is to 1, the sub-bottom section shows the relation of variable to constant as 1 is to 1.05 and the sub-sub-bottom section shows the relation of variable to constant as 1 is to 1.42. Thus it appears that only in the straight-line section does the metabolic power of the variable exceed the metabolic power of the constant and that the excess at that point is about 10 per cent. On the other hand, as one goes far down into the bottom section, the metabolic power of the constant becomes materially greater than the metabolic power of the variable.

Studies are now going forward on the relation of metabolic effect of variable and constant temperatures when the constant is run at the average of the variable in the different sections of the sigmoid curve of temperature reaction for *Culex pipiens*. The top section has been completed and the ratio between the metabolic power of the variable to the constant in that section is as 1 is to 1.—11-26-41.

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Refrigeration Test of Transforming Codling Moth Larvae

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Stocks of codling moth larvae for experimental work are usually collected in the late fall or winter months and are then often held for many months in cold storage until a short time before they are to be used. At the time of the year when such collections are made, the larvae are all of the hibernating brood and may be kept in cold storage a long time beyond their normal emergence period without serious lowering of vitality.

A test was made at Yakima, Wash., in 1941 and 1942 to determine whether larvae of the codling moth that would normally transform to moths the same season would suffer a loss in vitality if held in a refrigerator for use later in experimental work. Larvae were collected from burlap bands on apple trees July 11, 1941, and allowed to spin up in pupation sticks. Three days later they were placed in a refrigerator at a constant temperature of 40°F. and a humidity of 40 per cent. Twelve sticks were used for each test except the last, which had only seven. Four groups were removed at intervals of 14 days (table 1). To extend the test as long as possible the remaining groups were taken out at intervals of 30 days, with the exception of the last group, which was left in for an interval of 2 months.

Table 1.—Effect of refrigeration at 40°F. and on first-brood codling moth larvae.

Date Removed from Refrigerator	Days Refrigeration	Total Larvae	Per Cent Emerged
1941			
July 28	14	751	67.1
Aug. 11	28	686	54.8
Aug. 25	42	384	45.8
Sept. 8	56	516	27.9
Oct. 8	86	682	46.0
Nov. 8	117	680	22.2
Dec. 8	147	654	1.4
1942			
Jan. 8		797	.6
Mar. 8	237	434	.7

Larvae gathered at the same time and in the same manner, but held at normal outdoor temperatures, suffered a mortality of only 8 per cent, which was probably due to handling. No explanation is evident for the increase of emergence in the lot removed from the refrigerator in October. The small numbers that emerged from lots removed from the refrigerator during December, January, and March probably consisted chiefly of individuals that were destined to hibernate, since a small proportion of the first brood normally does not emerge until the following year.

As most of the larvae used were of the summer brood, it is remarkable that after nearly 5 months 22 per cent were still alive and able to transform into moths. However, it is not practicable to use this method for keeping transforming larvae for more than 2 weeks after collection, as the mortality is too great.—8-17-42.

The Introduction and Recovery of *Trissolcus murgantiae* Ashm. in California

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Trissolcus murgantiae Ashm., a scelionid egg parasite of the harlequin bug, was introduced into California from Mississippi in the fall of 1940, as a result of correspondence between H. S. Smith and C. P. Clausen, who kindly arranged for the collection and transmittal of parasitized eggs to the University of California Citrus Experiment Station.

The primary purpose in introducing *Trissolcus murgantiae* was for its use in parasite-host population studies. These studies were to be undertaken with two parasites, *T. murgantiae* and the indigenous parasite *Oöencyrtus johnsoni*. After rearing *T. murgantiae* for more than a year in the laboratory, however, it became apparent that use of this particular host-parasite group was impractical. *T. murgantiae* was then reared simply for field liberation.

It will be noted that relatively small numbers of *T. murgantiae* were liberated. Mass colonization of the parasite was impractical because of a shortage of hosts; laboratory bugs failed to lay many eggs and field egg populations were low during the period of liberation.

The first liberation, totaling 80 *Trissolcus murgantiae*, was made November 28, 1941, in South Covina on wild mustard (*Brassica campestris*) infested with the harlequin bug. Further liberations totaling 500 parasites were made January 30, February 4, and February 19, 1942, at Olive, on wild mustard infested with the harlequin bug. Finally, 200 parasites were liberated May 20, 1942, near Costa Mesa on bladder pod (*Isomeris arborea*). This perennial sustains harlequin bugs throughout the year in these coastal areas and therefore is an ideal host plant for establishment purposes. The parasite was recovered from eggs collected in this latter locality July 13, 1942. Permanent establishment is not yet certain but is very probable because of the abundant and constant supply of hosts on bladder pod.

Recoveries from the earlier liberations have not been attempted because when the original wild mustard stands were visited the plants had died out. The parasite may, of course, have become established and dispersed in these areas.

The sample of harlequin bug eggs collected near Costa Mesa on July 13, 1942, consisted of 617 eggs, 111 of which hatched. Of the 506 which did not hatch, 583 *Oöencyrtus johnsoni* and eight *Trissolcus murgantiae* were reared. Doubtless some of these 506 eggs contained unparasitized harlequin nymphs which failed to hatch. Even so, *O. johnsoni* accounts for approximately 80 per cent of the eggs. This is slightly higher than the North Carolina record of Huffaker (1941) for both *T. murgantiae* and *O. johnsoni* together, and it will be of interest to follow the progress of *T. murgantiae* in California and see if the species assumes the somewhat dominant role it has in the East, and whether it has any additional effect on the harlequin bug populations.—8-12-42.

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A Killing and Preserving Fluid for Immature Insects

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One of the drawbacks in the collection and preservation of immature insects has been the necessity of killing the specimens in hot water to insure their complete relaxation. Also, hot water treatment in some cases does not prevent darkening of normally light colored larvae, especially the Scarabaeidae and some Diptera. Living larvae placed directly in cold alcohol become contorted, contract their legs, and otherwise obscure morphological structures used in their identification.

Using housefly larvae, *Musca domestica* (L.), the writers made preliminary tests of the killing and preserving qualities of methyl, ethyl, propyl, butyl, and amyl alcohol. The longer the carbon chain of the alcohol and the older the larvae, the more rapid was the discoloration. If small quantities of acetic or hydrochloric acid were added to methyl or ethyl alcohol, the full grown maggots so treated did not darken, and the newly formed puparia did not turn brown.

In later random tests of various liquid compounds it was found that a mixture of dibutyl ether and ethyl alcohol caused some of the housefly larvae to burst open. These specimens remained white much longer than the intact larvae, indicating that the failure of the preservative to retard darkening was probably due to poor penetration. Therefore, further testing was restricted to mixtures containing organic solvents of fats, waxes, gums, and resins.

Of the various mixtures of liquids tried in many different proportions upon the larvae of the housefly and the southern armyworm, *Prodenia eridania* (Cram.), only one gave satisfactory results. This mixture contained an unsaturated 14-carbon ketone (2-methyl-7-ethyl-undecen-5-one-4), glacial acetic acetic acid and 99.5 per cent methyl alcohol in the proportion of 2:1:4 by volume. The ketone was obtained from the Carbide and Carbon Chemicals Corp., N. Y. Housefly larvae killed and preserved in this mixture have remained white and firm for over a year; southern armyworm larvae straightened out and died with the prolegs and crochets clearly visible. Both species became tough and somewhat rubbery and if flattened by pressure readily regained their shape.

Many insects of other orders have been satisfactorily killed and preserved in this mixture. Colors, except green, were generally retained longer than if alcohol alone were used. The mandibles of lepidopterous and coleopterous larvae were usually set wide open. Gross dissections of several forms showed that the internal organs remained in good condition.

The mixture was not equally satisfactory for all immature insects; e.g., the gills of ephemerid larvae became severely swollen. However, few aquatic species were adversely affected. Reduction of the proportion of acetic acid may improve results in some cases.

The mixture is transparent and amber-colored. If ethyl alcohol is substituted for methyl it gradually darkens and become opaque. An oily layer separates to the top after a few insects have been placed in it, but this causes no apparent loss in the killing and preserving qualities. The vapors are apparently nontoxic, possessing a lingering and somewhat unpleasant odor. It is less volatile than alcohol, and it does not appear to corrode cork or metal stoppers.

The 14-carbon ketone is not an established commercial product. This results in a moderately high initial cost. However, most specimens may be transferred without injury to 70 per cent alcohol after being killed and allowed to harden in the ketone mixture. War conditions limit its availability at present.—8-21-42.

Effect of Certain Larvicides on the Overwintering Larvae of the Clear Lake Gnat

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The effect of some common larvicides on the overwintering larvae of the Clear Lake gnat, *Chaoborus astictopus* D. & S., was studied at Nice Calif., during January, February, and March of 1939 and 1940. Although the use of larvicides does not appear practical as a control for the Clear Lake gnat, it is believed that the results of jar tests using 1-phenylbenzothiazole, phenothiazine, derris, and pyrethrum on such an unusual and highly sensitive insect might be of interest.

Chaoborus larvae are different from the more familiar culicid larvae in that respiration is by gills and the larvae do not normally come to the surface. They are predacious and selective in capturing their prey and therefore cannot be controlled by stomach poisons. The only feasible larvicides are those which kill by contact and remain in solution or finely divided suspension.

CHEMICAL COMPOUNDS AND MIXTURES.—The materials tested were phenothiazine (thiodiphenylamine), powdered derris root (5 per cent rotenone), 1-phenylbenzothiazole in a mixture of diesel oil 3 parts and carbon tetrachloride 2 parts (1 g. of 1-phenylbenzothiazole per 100 cc. of solvent), and pyrethrum solution (1 g. of total pyrethrins per 100 cc. of a mixture of diesel oil 3 parts and carbon tetrachloride 2 parts). The phenothiazine and derris were of commercial grade. The other two materials were made up in the Division of Insecticide Investigations of the Bureau of Entomology and Plant Quarantine. The only wetting agent used was a mixture of sodium lauryl sulfate and an alkylhydroxyphenylbenzenesulfonic acid.

PROCEDURE.—The tests were made on overwintering larvae in wide-mouth pint jars at temperatures of 50 to 60°F. The larvae were placed in the jars and the volume of water built up to 200 cc. The test solution was added with such additional water as to make a total of 300 cc. in each jar.

The tests were replicated and observations were made daily for 72 hours except that with some compounds, especially phenothiazine, examinations were made for a longer period. Objections might be raised to taking mortality counts after as much as a week, since death may be hastened because the larvae are in a weakened condition from remaining inactive and unfed. However, 24, 48, or even 72 hours is not a satisfactory period, for larvae that would be classed as inactive and therefore dead according to usual methods might later recover.

DISCUSSION.—Pyrethrum solution was more toxic to the overwintering larvae than the other com-

pounds (see table 1). Concentrations of total pyrethrins as low as 0.1 p.p.m. of solution gave good kills in the test jars. The wetting agent did not increase the performance of the pyrethrum solutions, but it gave a smoother mixture, which was easier to handle, and gave a more uniform kill. Since larvae affected by pyrethrins come to the surface, they were no doubt affected by the oil separating out and also coming to the surface. Death of the larvae therefore may have resulted from contact with a higher concentration of toxic materials than that indicated. However, the media in such cases was toxic enough to affect the larvae to such an extent as to force them to the top of the water.

Table 1.—Effectiveness of the various chemicals against overwintering larvae of *Chaoborus astictopus*.

LARVICIDE AND CONCENTRATION IN P.p.m.	REPLICATIONS	LARVAE	PER CENT MORTALITY
Phenothiazine			
0.33	9	180	100
.1	7	140	100[1]
.066	6	120	11.6
.05	6	120	5.8
Powdered derris root (5 per cent rotenone)[2]			
1.0	6	120	98.3
.5	6	120	97.5
.33	5	100	93.0
.2	6	120	75.8
.1	5	100	42.0
.05	5	100	21
1-Phenylbenzothiazole			
.33	5	100	100
.2	5	100	66
.1	5	100	33
.05	5	100	3
Pyrethrum solution[3] without wetting agent			
.33	5	100	100
.2	5	100	99
.1	5	100	93
.033	5	100	66
Pyrethrum solution[3]			
.2	5	100	100
.1	5	100	93
.033	5	100	63
.016	5	100	36

[1] 100 per cent kill only when moribund larvae were classed as dead.
[2] Concentration based on rotenone.
[3] Concentration based on total pyrethrins.

The pyrethrins act on the nervous system of the larvae, and muscular contraction occurs. The body walls are not kept distended by the body fluid, and the longitudinal muscles in contracting cause a decrease in larval length. The posterior segment that supports the anal fin becomes limp, and the larvae lose their power of locomotion. The nervous system may be able to carry stimuli to the voluntary muscles, but only a continuous quivering of the body results from tonic convulsions. The contraction of the heart becomes feeble and the rate is decreased. The gut action is very feeble, although peristaltic constrictions continue. Recovery from low concentrations occurs after several days.

The wetting agent used was not toxic to the larvae in strong concentrations. The carbon tetrachloride was very toxic. Complete tests on its toxicity or possible synergistic action were not made.

Phenothiazine apparently affects the nervous system. The larvae retain their normal shape and size and sink to the bottom of the test jars. In this condition they do not respond to prodding with a needle. Apparently the voluntary nervous system is affected, but heart action continues. The gut action is weak and irregular. Some of the muscles of the body wall twitch, but the action is not constant, nor is it so pronounced as in larvae affected by pyrethrum. In larvae treated with phenothiazine a dark-brown material was observed in the malpighian tubes in the section next to the gut. Larvae have been observed to remain in this condition for 3 weeks. Larvae that remained completely immobile for 4 days have recovered from the effects of phenothiazine.—8-21-42.

Mixing Poisoned Bait for the Tobacco Budworm

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Experiments and commercial practice have shown that a poisoned bait consisting of lead arsenate[1] and corn meal in the proportions of 1 to 75 by weight serves as an efficient control of the tobacco budworm, *Heliothis virescens* (F.), on shade-grown and sun-grown tobacco. Although considerable data have been accumulated regarding this control, little definite information has been available concerning the efficiency of the mixing methods generally employed in its preparation. The larger tobacco-producing companies utilize mechanical mixers in preparing the bait, and it seems rather certain that thorough mixing of the ingredients is obtained by this method. The mixing of bait in limited quantities in pails, tubs, and boxes by hand has, however, been open to some question.

To obtain information concerning the various bait-mixing methods commonly employed by tobacco growers, half-bushel lots of the bait were prepared by six methods. The ingredients, corn meal and lead arsenate,[2] 1 to 75 by weight, were measured at the laboratory, but each lot was mixed by the growers in accordance with their usual procedure, with the exception of the "experimental mix." The methods employed were as follows: (1) Power-operated mechanical mixer, (2) home-made barrel mixer, (3) hand mix in wash tub, (4) hand mix in 5-gallon bucket, (5) box and hoe method, and (6) experimental mix (hand-operated mechanical mixer). The time consumed in mixing each lot of bait by the six methods was 2.5, 10, 8, 9, 11, and 5 minutes, respectively.

The six lots of bait were tested for relative efficiency in a field of cigar-binder tobacco at Quincy, Fla., during the 1940 growing season. Each plot receiving a bait treatment consisted of one row of tobacco 170 feet long, containing 156 plants. The series of six treatment plots were laid out at random on adjacent blocks of tobacco. The bait was applied to the buds with the fingers in the usual manner about twice each week, with a total of 16 applications for the season. This frequency of applications is usually necessary to give cigar-binder tobacco adequate protection against budworms in this locality.

A heavy infestation of budworms occurred in the experimental field, as evidenced by the numbers of larvae on the unpoisoned check plants and by the relative abundance of eggs and adults present. The

average commercial loss on the unpoisoned plants due to the feeding of the insent was estimated at approximately 72 per cent of their value.

One hundred plants were examined in each plot and a total of 300 per treatment. The results are given in table 1. These data indicated that efficient control of the budworm was obtained with each of the bait-mixing methods. In all treated plots the estimated reduction in value of the tobacco was less than 1 per cent.

Table 1.—Relative budworm control obtained with bait mixed by the various methods.

Bait Mixing Method	Number of Leaves		
	Examined	Fed Upon	Damaged
1	4,972	21	3
2	4,841	17	9
3	5,026	20	11
4	4,823	11	5
5	4,886	14	9
6	4,786	14	5

Chemical analyses were made of duplicate samples of each bait mixture and are shown in table 2. In reporting the results of these analyses R. C. Roark states that "with the possible exception of I.D. 5626 and 5628, these results would indicate a satisfactory uniformity of mixing by the different methods."

Table 2.—Analyses of poison mixtures.[1]

Bait-Mixing Method	I.D. No.	Arsenic Pentoxide Per Cent
1	5626 A	0.42
	B	.38
2	5627 A	.41
	B	.41
3	5628 A	.35
	B	.43
4	5629 A	.43
	B	.42
5	5630 A	.43
	B	.43
6	5631 A	.43
	B	.42
Theoretical value		.43

[1] Made by the Division of Insecticide Investigations, Bureau of Entomology.

As a result of these rather limited experiments, it is concluded that satisfactorily mixed poisoned bait for budworms may be prepared by each of the methods included in the tests.—8-12-42.

[1] Ordinary commercial grade of acid lead arsenate.
[2] Contained 32.8 per cent of total arsenic pentoxide and 0.28 per cent of water-soluble arsenic pentoxide. Analysis was made by the Division of Insecticide Investigations, Bureau of Entomology and Plant Quarantine.

The Resistance of Citrus Thrips to Tartar Emetic—Sucrose Treatment

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Tartar emetic was first tested against citrus thrips, *Scirtothrips citri* (Moult.), in 1937 (Boyce & Persing, 1939) and subsequent studies (Persing *et al.*, 1940) conducted at the University of California Citrus Experiment Station have resulted in the development of the tartar emetic-sucrose spray which has been used extensively since 1939. Treatment with this spray has been considered ideal because it affords highly effective results and is simple and relatively inexpensive. However, an exception to this generally favorable condition became evident in certain lemon groves in the San Fernando Valley, California, during the late summer and fall of 1941. Treatment applied at this time gave very poor results and subsequent chemical and biological studies have demonstrated that citrus thrips in this district have become "tolerant" or "resistant" to tartar emetic treatment. In one particular grove in the San Fernando Valley, a treatment consisting of 12 pounds of tartar emetic and 12 pounds of sucrose per acre applied in the 1942 season afforded very poor results. In this same grove, treatment consisting of 3 pounds of tartar emetic and 3 pounds of sucrose per acre gave excellent results during the early summer of the 1941 season. While genetical and toxicological studies are not yet complete, it is probable that a biological race of this species has developed that is strikingly resistant to tartar emetic-sucrose treatment in comparison with populations that formerly existed in this particular area and that still exist in other lemon districts. This phenomenon has not been observed in any other lemon district and present indications are that it is limited to approximately 300 acres out of a total of about 3600 acres in the San Fernando Valley.

Table 1.—Survival of citrus thrips from two localities, the "resistant area" in the San Fernando Valley and the Upland district, in southern California, on lemon leaves sprayed in the laboratory with tartar emetic and sucrose.

Source of Thrips	Adults		Larvae	
	Total	Survival (per cent)	Total	Survival (per cent)
Sprayed leaves, 5.0 micrograms each, tartar emetic and sucrose per square centimeter				
"Resistant area"	1598	6.1	193	36.3
Upland district	1512	0.1	164	0.0
Sprayed leaves, 2.5 micrograms each, tartar emetic and sucrose per square centimeter				
"Resistant area"	1365	19.3	308	78.2
Upland district	1695	0.0	100	1.0
Unsprayed leaves				
"Resistant area"	266	22.9	22	77.3
Upland district	126	18.3	7	85.7

It is of interest to note that in the Upland, California, district, which has been treated as extensively with tartar emetic-sucrose sprays as the resistant area in the San Fernando Valley, this treatment is still highly effective.

In a preliminary experiment, thrips collected in the resistant area of the San Fernando Valley were compared with thrips collected in the Upland dis-

trict on sprayed abscised leaves, according to the method for testing toxicity described by Munger (1942). Two dosages were used in this comparison, namely 2.5 and 5.0 micrograms of tartar emetic per square centimeter of leaf surface with an equal quantity of white sucrose. Leaves were infested in both districts and were taken to the laboratory where they were kept under controlled conditions of temperature and humidity for 3 days, after which time mortality counts were made. Results of this experiment are presented in table 1.

While this experiment is not extensive, it furnishes rather striking evidence that citrus thrips from these two localities differ greatly in their ability to survive on leaves sprayed with tartar emetic and sucrose.—10-2-42.

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Brassica campestris L. and *Raphanus raphanistrum* L. as Breeding Hosts of the Green Peach Aphid[1]

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Field observations in northeastern Maine during the latter half of July 1941, in connection with a study of the biology of aphids infesting potatoes in this region, disclosed that large numbers of the green peach aphid, *Myzus persicae* (Sulz.) and of the buckthorn aphid, *Aphis abbreviata* Patch, were developing on the leaves of wild rutabaga, *Brassica campestris* L., and wild radish, *Raphanus raphanistrum* L. These two weeds, as well as several other species of *Brassica*, are considered as being among the most serious weed pests of cultivated crops in this agricultural area. They were very abundant and many of their leaves held more than a thousand aphids each. In some districts the infestation was found to consist predominantly of the green peach aphid, whereas in other districts it was found to be composed almost entirely of the buckthorn aphid. Observations indicated that many of the aphids in these colonies were nymphs having wing pads.

Although plants belonging to both genera have been recognized as hosts of both species of aphids, little was known regarding their importance as breeding hosts when mean temperatures are high enough to favor rapid aphid reproduction. A study was therefore undertaken to gain information respecting their probable importance as a source of the winged aphids of both species, which commonly move to potatoes during August and September.

On July 28 field growing plants were caged, in most instances singly, so that approximately equal numbers of each plant species were in each of three stages of development. These stages were designated as young, early-flower, and mature. In addition to a natural infestation of aphids, half the plants in each series were artificially infested with an average of 4.4 adults and 33.6 nymphs of the green peach aphid per plant. The remaining half of the plants were infested with an average of 8.3 adults and 82.4 nymphs of the buckthorn aphid per plant. At intervals of 4 to 10 days during the period between August 8 and September 24 all winged aphids on each plant in both series were carefully removed and later identified and counted.

Large numbers of winged specimens of the green peach aphid matured on the caged plants of both series. Few winged specimens of the buckthorn aphids were observed on plants in the field during late July, it seems possible that their period of productiveness on these weeds had passed when the cage studies began. Relatively small numbers of the potato aphid, *Macrosiphum solanifolii* (Ashm.), the turnip aphid, *Rhopalosiphum pseudobrassicae* (Davis), and the cabbage aphid, *Brevicoryne brassicae* (L.), also were recovered from the plants under observation.

The average number per plant of winged *persicae* recovered from plants artificially infested tended to be greater than the average per plant recovered from those plants not so infested. However, the plant-to-plant variation in the numbers of winged *persicae* recovered was so great that for the purpose of this study the difference between artificially and naturally infested plants can be disregarded. Replications were not adequate to determine whether there was a significant difference in numbers of winged *persicae* recovered from plants of the two species.

The average numbers of winged *persicae* per plant recovered from the two species of weeds during August and September were 857, 628, and 143, respectively, for those plants classed as mature, early-flower, and young (table 1). The largest numbers recovered at any one period of observation were removed from mature plants on August 23. The corresponding periods for the early-flower and young plants were somewhat later. The largest numbers of winged aphids recovered from all the caged plants were taken during the periods of heaviest catches of winged aphids in aphid traps which were operated nearby.

Table 1.—Winged *Myzus persicae* recovered from caged *Brassica campestris* and *Raphanus raphanistrum* during August and September 1941 at Presque Isle, Maine.

	Stage of Plant When Caged					
	Mature		Early-flower		Young	
Date	Plants	Aphids per Plant	Plants	Aphids per Plant	Plants	Aphids per Plant
Aug. 8-9	8	19.6	6	8.0	5	5.8
13	8	45.3	9	25.9	5	17.0
16-19	8	168.1	9	83.9	5	8.7
23	8	419.8	9	130.7	5	47.0
Sept. 3	5	190.0	6	169.5	3	43.0
8	2	9.5	3	164.3	3	8.0
15	1	4.0	3	33.3	2	7.5
24	1	1.0	1	12.0	2	6.0

Injury to the foliage of the caged plants from frequent handling and from the feeding of caterpillars, as well as an outbreak of a fungus disease affecting

[1] Cooperative investigations of the U. S. Department of Agriculture and the Maine Agricultural Experiment Station.

the developing aphids during the last 10 days of August, appeared to be the more important factors limiting the numbers of winged aphids that matured on the plants. Whereas the numbers of winged *persicae* normally maturing on these plants in the open may be greater, or less, than found for caged plants, the average number recovered from the mature plants in this test was large enough to infest, one to the plant, every potato plant growing on 0.06-acre of land. Considering the apparent ease with which this plant louse moves extensive distances and its high reproductive capacity, together with its effectiveness as a vector of leaf roll and other virus diseases of potato, the potential importance of these two species of weeds as sources for aphid infestation of potatoes is readily understood.

Two Activators for Pyrethrins in Fly Sprays

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Many materials have been tested in an effort to find substitutes for part of the pyrethrins often used in fly sprays having highly refined light petroleum oil as a base. Two materials that have been found to be highly toxic to the housefly, *Musca domestica* L., when incorporated into such sprays are ethylene glycol ether of pinene (Pierpont 1939) and sesame oil (Eagleson 1940).

Methylphenylnitrosoamine, found toxic to screwworm larvae by Bushland (1940), and 2,4-diamylcyclohexanol activated the pyrethrins present in highly refined kerosene, as shown by a marked rise in mortality of houseflies when tested by the turntable method. The methylphenylnitrosoamine, $C_6H_5N(CH_3)NO$, was a light-brown liquid at room temperature, had a noticeable odor, and was relatively free from impurities. The 2,4-diamylcyclohexanol, $[CH_3(CH_2)_4]_2C_6H_9OH$, was a colorless, viscous liquid at room temperature, had little if any odor, and was of a high degree of purity. Both materials were purchased from commercial sources. When used alone in highly refined kerosene, they caused mortalities of 6 and 11 per cent, respectively, at 2 per cent concentration and 11 and 12 per cent at 5 per cent concentration.

Table 1.—Mortality of houseflies from refined-petroleum-oil sprays containing 0.5 mg. of pyrethrins per milliliter of spray plus an activator. Six replicate tests averaging 146 flies per test.

Activator	Concentration, per cent by volume	Mortality after 2 days, per cent[1]
Methylphenylnitrosoamine	3.0	65
	1.0	32
	0.5	20
	0.125	13
2,4-Diamylcyclohexanol	5.0	43
	1.0	24
None (check)[2]		25

[1] Differenecs in mortality of 18 per cent or more are significant.
[2] The Official Test Insecticide of the National Association of Insecticide and Disinfectant Manufacturers was used. The pyrethrins content is approximately 1 mg. per milliliter. The mortality is lower than that generally obtained with this insecticide.

The results, which are summarized in table 1, show that 3 per cent of methylphenylnitrosoamine caused a highly significant and 5 per cent of 2,4-diamylcyclohexanol a significant increase in mortality over that obtained with the standard pyrethrins-oil spray used as a check.

When placed in clear-glass bottles on a laboratory bench and exposed to daylight for 4 weeks, the spray containing 3 per cent of methylphenylnitrosoamine developed a slight dark discoloration, and after 10 weeks all samples containing this amine showed dark discoloration. Under similar conditions the sprays containing 2,4-diamylcyclohexanol showed no discoloration.—10-5-42.

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The Nature of "Cobalt" Once Recommended for Control of the Tobacco Hornworm

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Tobacco growers in Kentucky and Tennessee sometimes use a poisoned bait for combating the adult tobacco hornworm, *Protoparce sexta* (Johan.). This bait is prepared by mixing an insecticide with a sugar solution, and is placed in the corollas of jimsonweed (*Datura stramonium*), which belongs to the same family as tobacco. Imitation jimsonweed blossoms made of china have also been used as receptacles for the bait. One of the insecticides formerly used in preparing this lure was called "cobalt."

The origin of the use of "cobalt" is rather obscure. In 1850–51 Glover (1855), of Mt. Pleasant, Fla., reported that "cobalt" and sweetened water, when applied to the flowers of tobacco, jimsonweed, and gourd, gave marked success in destroying hornworm moths. The use of "cobalt" with honey or sweetened water placed in jimsonweed blossoms is also mentioned in more recent literature (Kentucky Agricultural Experiment Station 1894; Moodie 1897; Howard 1900; McNess *et al.*, 1907; Scherffius & Woosley 1909; Morgan 1910; and Gilmore & Milam 1933). The nature of the material referred to as "cobalt" is not indicated in most of these references. Morgan (1910) specified arsenide of cobalt, or fly stone, which Webster's Dictionary defines as a "native cobalt arsenide, used as a fly poison by grinding it and adding it to sweetened water." Since hornworm moths are still known as tobacco flies in some sections of the country, there is probably some connection between the use and the name.

Metallic cobalt and its salts with the common acids are not recognized as insect poisons. Several that were tried by Gilmore & Milam (1933) against the tobacco hornworm moths were not toxic. Compounds which in addition to the arsenide contain both cobalt and arsenic include cobalt arsenic sulfide

Table 1.—Chemical Composition of "Cobalt" Poisons

	"Cobalt Poison"			"Black Cobalt"
	I.D. 4144A	I.D. 4144B	I.D. 4170	I.D.5746
Cobalt (CoO)	52.8	None	None	None
Arsenic (As_2O_3)	45.6	68.3	66.3	76.8
Manganese (MnO_2)	None	20.2	Trace	12.6
Silicon (SiO_2)	—	3.9	—	—
Phosphorus (P_2O_5)	—	1.9	—	—
Iron (Fe_2O_3)	—	—	10.3	Present[1]
Carbon	—	—	9.0	—
Sulfur (SO_3)	—	—	2.2	Present[1]
Magnesium	—	—	—	Present[1]
Water	Trace	5.5	2.3	None
Aluminum	—	—	3.8	—

[1] Qualitative analyses only.

(cobaltite), earthy cobalt arsenate (cobalt crust), cobalt arsenate or phosphate (cobalt red), a hydrated oxide of cobalt and manganese (black earthy cobalt), and cobaltous arsenate (erythrite).

Four samples of materials formerly sold for this purpose, which were labeled "cobalt poison" or "black cobalt," were recently received at this laboratory. They represented old stocks of material from Georgia and Kentucky. Chemical analyses on these samples gave the results shown in table 1.

The ratio of cobalt to arsenic in sample I.D. 4144A is practically identical with the theory for cobaltous arsenate (erythrite). However, the arsenic in this sample was present largely as arsenite, as determined by qualitative tests, and the theoretical amount of water of crystallization in the mineral was absent. It is possible that the sample consisted of ignited erythrite, because ignition might result in the simultaneous oxidation of cobalt and reduction of arsenic to the arsenious form.

Microscopic examination revealed the presence of free white arsenic (As_2O_3) in samples I.D. 4144 B, 4170, and 5746. Free manganese dioxide was detected by qualitative tests in I.D. 4144 B. The analyses indicate that arsenic is the toxic element common to all four samples. Manganese is present in two, and cobalt in only one. The reason for the adoption of the name "cobalt" is not apparent.

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The Median Lethal Dose of Calcium Arsenate for the Honeybee[1]

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The steady increase in the use of arsenicals to control the insect pests of cotton has created a serious hazard for the beekeeper. Calcium arsenate, most popular insecticide for use on cotton, each year kills thousands of colonies of bees which visit cotton fields to collect nectar and pollen. The work here in reported was conducted during the summer of 1939 to determine the dose of calcium arsenate which is fatal to bees. A knowledge of the toxicity of calcium arsenate to the honeybee contributes to the information needed to aid the beekeeper in reducing his losses.

A calcium arsenate containing 42.99 per cent total As_2O_5 and 7.3 per cent water-soluble As_2O_5 (New York method of analysis) was selected for these tests because it was considered to be representative of the dusts in common use in Texas. The bees were induced to eat the calcium arsenate by mixing it with queen candy, a semi-solid mixture of powdered sugar and honey.

Glass cups 12 mm. in diameter and 6 mm. in height were filled with the candy which contained a known percentage of calcium arsenate. Each bee was fed individually from a cup of candy after it had been oven-dried to a constant weight.

The bees were placed in No. 13 gelatin capsules that had holes approximately 2 mm. in diameter in one end. After the body weight of a bee was obtained, it was allowed to feed from a cup of the poisoned candy by pushing its proboscis through the hole in the end of the capsule. It could reach the surface of the candy with the tip of its labium, but not with any other part of its body. Varying doses were administered by changing the time that the different bees were allowed to feed. After a bee had fed the desired number of minutes it was moved to unpoisoned candy and the poisoned candy was again dried to a constant weight to ascertain the amount that the bee had consumed. At the end of 24 hours the bee was recorded as being dead or alive.

The doses administered to 145 individual bees were arrayed according to the size and grouped in groups of ten and the mortality observed in each group was

[1] Abstract of a thesis submitted to the Department of Entomology of the Agricultural and Mechanical College of Texas in partial fulfillment of the requirements for the degree of Master of Science. The writer wishes to express his appreciation to Dr. S. W. Bilsing, under whose direction the work was done.

expressed in per cent. Using the method of Bliss (1938), the dosage-mortality curve for these data was calculated (Fig. 1) and the median lethal dose was found to be 0.039 mg. of calcium arsenate per gram of body weight.—8-2-42.

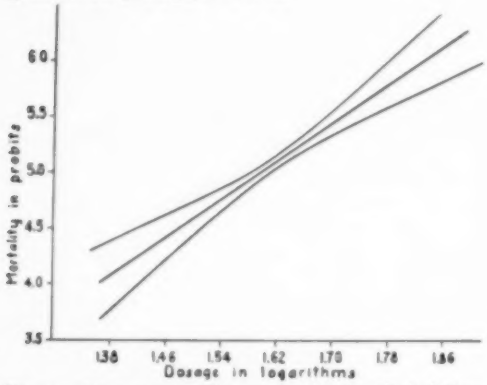

FIG. 1—Dosage-mortality curve. Median lethal dose of calcium arsenate for the honeybee.

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The Vetch Bruchid in Georgia[1]

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Several species and varieties of vetch (*Vicia sp.*) have been grown at Experiment, Ga., annually since 1936 for the purpose of making records of their diseases. Plantings were made in triplicate in parallel rod rows. Knowing that the vetch bruchid, *Bruchus brachialis* Fahr., was prevalent in neighboring states and that one specimen had in fact been collected in DeKalb County, Georgia (Bottimer 1936), every harvest was watched for this pest, but none appeared until this year. The seed was kept each year without fumigation, hence bruchids if present should have been found. In June, 1942, many adult bruchids[2] appeared in the newly harvested seed and the various lots were then examined separately to determine the percentage producing adult weevils, with the results as shown in table 1.

Two species of vetch were infested, *Vicia villosa* Roth. and *V. dasycarpa* Ten. Seeds of these were examined in lots of 200 in which infestations ranged from 1.5 to 11.5 per cent, with average percentages as given in the table. Seeds of *V. sativa* L., *V. monanthos* (L.) Desf., *V. grandiflora* Scop., and *V. atropurpurea* Desf. did not produce any bruchids.

Pinckney & Stitt (1941), from tests made in North Carolina, reported somewhat similar results as to the susceptibility of species. *Vicia villosa* and *V. dasycarpa* were heavily infested, *V. atropurpurea* moderately so, and *V. sativa* and *V. pannonica* Crantz lightly infested. As yet the damage to vetch seed in Georgia does not appear to be as severe as that in North Carolina.

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[1] Cooperative investigations between the Division of Forage Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture, and the Georgia Experiment Station, Experiment, Ga.

[2] Determined by H. S. Barber, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, Washington, D. C. as *Bruchus brachialis* Fahr.

Table 1.—Infestation of vetch seed by the vetch bruchid at Experiment, Georgia, in 1942

SPECIES OF VETCH	ACCESSION NUMBER OR ORIGINAL SOURCE OF SEED	COMMON NAME OR NUMBER	DATE OF HARVEST	SEEDS EXAMINED	SEEDS PRODUCING WEEVILS	
				Number	Per Cent	
Vicia villosa	F. C. 22182	Smooth	June 8	800	4.1	
	Oregon	Smooth	June 8	400	5.0	
	Alabama	Smooth	June 8	1,200	7.7	
Vicia dasycarpa	F. C. 22471	Woolypod	June 8	800	3.6	
Vicia sativa	Oregon	Alba	June 9	2,476	0.0	
	Oregon	Willamette	June 9	645	0.0	
	Oregon	Selection #7	June 9	189	0.0	
	Oregon	Oregon Common	June 9	738	0.0	
	F. C. 16462	—	June 8	1,833	0.0	
	F. C. 22666	—	June 9	417	0.0	
	Oregon	Selection #5	June 9	210	0.0	
	F. P. I. 81566	—	June 9	801	0.0	
	F. P. I. 119988	—	May 26	299	0.0	
	F. C. 29933	—	May 26	875	0.0	
	F. C. 18808	—	June 18	785	0.0	
Vicia monanthos	Oregon	Monantha	May 26	1,950	0.0	
Vicia grandiflora	F. C. 29930	—	May 11	6,688	0.0	
Vicia atropurpurea	Oregon	Purple	June 9	2,625	0.0	

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Common Names of Insects

WITH THE SCIENTIFIC NAMES of insects in perpetual chaos, due to the application of the law of priority, the splitting of species and generic concepts, and the endless shuffling of species from one genus to another, common names have come to have much more significance and importance than formerly. Indeed many of the good old common names are a better index to the species under consideration than the scientific names. The principal reason for employing scientific names was to avoid confusion, to assure stability, and have a single name for each species, which would be intelligible in all countries, thus making possible universal understanding of the insect under consideration in any description or reference.

It has continually been emphasized that the scientific name is far superior to a common name, because more than one common name may be applied to the same species, especially in different regions or countries of the world; the implication being that only one scientific name would be applied to a given species.

I think it is fair to challenge whether the system of scientific names is accomplishing any one of the desiderata cited above. So far as the scientific names of economic insects are concerned, we *do not* have fixity, and we do have a multiplicity of names applied to the same species. The generic or specific names of more than two-thirds of our common economic insects have been changed from one to half a dozen times since the species was first described.

Formerly entomologists appended a scientific name to their publication to make clear what insect was meant by the common name used. Conditions are now such that an entomologist, using the current scientific name, would do well to append the approved common name, so that his readers may be able to find out what insect he is talking about. Particularly, since the American Association of Economic Entomologists has given approval to the common names of many of our best known insects, these common names have come to be more stable, dependable, and meaningful, less evanescent and subject to synonymy, than the corresponding scientific names.

It is not my intention to try to discuss all of the possible criticisms of common names. But there is one principle which, I think, is so sound, so simple, and so sensible that I present it for consideration, and hope it will be generally adopted.

The principle may be stated in this way: When the substantive part of a common name, is correctly applied, as *fly* for Diptera, *beetle* for Coleoptera, *wasp* for Hymenoptera, *tick* for Acarina, *bug* for Hemiptera, *worm* for Annelida, *louse* for Anoplura or Mallophaga, *moth* for Lepidoptera, *flea* for Siphonaptera, and the like, the distinguishing part of the common name shall stand as an adjective—a separate word. I can see *no reason whatever* for combining or hyphenating such words as the following, as is so often done. I think they should be written separately.

house fly	lace bug	lady beetle
drone fly	stink bug	flea beetle
deer fly	toad bug	leaf beetle
horse fly	wheel bug	cigarette beetle
bot fly	bed bug	wood wasps
blow fly	red bug	cuckoo wasps
bee flies	mealy bug	apple maggot
crane flies	hag moth	buffalo gnat
fruit flies	bee moth	gall gnats
moth flies	bud moth	bean weevil
crab louse	dog tick	grain weevil
body louse	dog flea	cattle tick
earth worm	rat flea	codling moth
gall aphid	honey bee	lappet moths
range caterpillar		

But *when these substantives are used* in an *entirely false, arbitrary, and misleading sense*, as in the following examples where the terms flies, worms, bugs, crickets, etc., do not refer to the proper orders or phyla, let us help the tyro by warning him that they do not carry their true meaning. This can easily be done by combining the sub-

stantive with its modifying or distinguishing name, if this does not make the name unduly long or awkward; or by the use of the hyphen, if the combined word looks too formidable.

butterflies (Lepidoptera)
dragonflies, damselflies (Odonata)
may-flies* (Ephemeroptera)
sawflies ichneumon-flies (Hymenoptera)
whiteflies, suckfly (Hemiptera)
scorpion-flies (Mecoptera)
caddice-flies (Trichoptera)
stone-flies (Plecoptera)
fireflies, spanish-fly* (Coleoptera)
dobson-flies, alder-flies (Neuroptera)
lacewinged-flies (Neuroptera)
green-flies (Homoptera, Aphididae)
citrus blackfly (Homoptera, Aleyrodidae)
to distinguish it from
adirondack black fly* (Diptera)

cutworm
budworm
bollworm
armyworm
oakworm
webworm
armyworm
spanworm
wireworm
fruitworm
jointworm
cabbageworm
carpenter-worm
white-ants,
coulee-cricket, mormon-cricket,* and camel-cricket (not Gryllidae).

bluebug (Acarina)
sowbugs (Crustacea)
pillbugs (Crustacea)
billbugs (Coleoptera)
june-bugs* (Coleoptera)
bee-louse (Diptera)
book-louse (Corrodentia)
fishmoth (Thysanura)
pear-slug (Hymenoptera)
sheep-tick (Diptera)
bat-ticks (Diptera)
aphid-lion (Neuroptera)
snow-flea (Collembola)
cattle-grubs (if used)

* See next to last paragraph of this article.

A worm is a member of the Phylum Annelida. When this term is applied to insect larvae, its false meaning can easily be indicated by the combined or hyphenated words. "Bug" has a technical meaning for Hemiptera and Homoptera but is widely applied to other insects and even to some Arthropods that are not insects at all. The uncombined terms "louse," "tick," "cricket," and "moth" should be applied only to Anoplura and Mallophaga, Acarina, Gryllidae, and Lepidoptera, respectively.

Too often writers seem to have followed the principle that, if the substantive and its qualifying term are short words, they should be combined. Thus we have bedbug, but not assassinbug or Harlequinbug; and earthworm but not thornheadedworm.

"Hopper" has no particular taxonomic significance so the distinguishing and qualifying part of the name should be combined with it:

grasshopper
leafhopper
treehopper
fleahopper
plant-hopper
frog-hopper

We have been accustomed to using grasshopper as one word for decades, but many writers still separate exactly comparable expressions into leaf hopper or leaf-hopper, tree hopper, flea hopper, etc.

We desire to make our science useful and popular and we owe a great deal to our non-technical readers and audiences and to struggling students who try, in a course or two, to grasp all the complicated and intricate concepts of our highly technical science.

To expect them to understand that, when we say lady bird (two words) we mean a beetle and not a female feathered animal, like all true birds, is expecting too much and running a totally unnecessary and useless risk. Silverfish, written as one word, is not so likely to be confused with the finny and scaly Pisces. On the other hand, cat fish and sun fish should each be wirtten as two words. When they read a sentence such as the Cornell student's famous sentence, in reporting upon a field trip: "We stopped by the spring and were charmed by the song of the red-admiral," the hypen would show that he did not mean an officer in the navy, although it could not show that he meant to say red bird. How shall we expect our readers to know, that if we write "walking stick" as two words, we are not referring to a cane; that "death watch," entomologically speaking, is neither a wake nor a time piece; that "harvest men" are not hired hands combining wheat or soybeans; that "the painted lady" (unless hyphenated), is not a woman in a circus sideshow. That an "ear wig" (two words) is not made of hair. And that "ant lions" and "woolly bears" are hexapods and not quadrupeds.

According to this principle, one would write may-flies with a hyphen, because they are not Diptera—true flies; but may beetles as two words, because they are beetles—Coleoptera. Likewise, pillbugs is combined, becase they are not bugs, but Crustacea; while pill beetles are separate

words. Rose-bug, applied to the rose chafer, a beetle, should be hyphened. Rose-slugs are sawflies, Hymenoptera, therefore hyphened; reserving the separate term "slug" for Mollusca. Snow-flea, as used for certain Collembola, requires the hyphen; but the term applied to Siphonaptera should stand as a separate word. For example, cat flea, not catflea or cat-flea. "Tick," when applied to the louse-like flies, needs to be distinguished from the term as applied to the Acarina. Some writers do this by placing the word in quotation marks, but I think the hyphen is better; thus, sheep-tick. Still better would be the English name ked for this insect. Sawfly, not being a fly, is properly a single word.

That there is great lack of uniformity in usage, will be apparent to anyone who will examine the names in the indexes of current text books and journals. Even the approved list of the American Association of Economic Entomologists exhibits what seem to me to be glaring inconsistencies.

Lacebug should be lace bug.
Bedbug should be bed bug.
Carpenter worm should be carpenter-worm.
Cattle biting-louse should be cattle chewing louse, because it is a louse but it does not bite in the sense that mosquitoes and fleas bite.
Common red spider should be either red-spider or red spider mite, to show that it is not a spider.
Corn lantern fly should be corn lantern-fly.
Cotton leaf worm should be cotton leafworm.
Cabbage worm should be cabbage-worm.
False chinchbug should be false chinch bug.
Fir bark louse should be fir bark-louse.
Garden flea hopper should be garden fleahopper.
Green clover worm should be green clover-worm.
Greenhouse stone cricket should be greenhouse stone-cricket.
Green stinkbug should be green stink bug.
Green-striped maple worm should be green-striped mapleworm.
Hickory shuck worm should be hickory shuck-worm.
Currant worm should be currant-worm.
Navel orange worm should be navel orange-worm.
Orange-striped oak worm should be orange-striped oakworm.
Painted lady should be painted-lady or painted-lady butterfly.
Potato tuber worm should be potato tuberworm.
Say's stinkbug should be Say's stink bug.
Sheep botfly should be sheep bot fly.
Stablefly should be stable fly.
Tissue paper bug should be tissue paper-bug, or better tissue-paper beetle.
Tobacco worm should be tobacco-worm.

(Several others might be added.)

Beyond this one principle I do not care to attempt to straighten out the tangle of combined or hyphened words, but since there is such utter lack of uniformity and agreement, I think it is probably best to use hyphens as sparingly as good taste will permit.

It seems to me probably wisest not to hyphenate or combine at all unless the combination or hyphen is needed to show that the substantive part of the name is used in a false sense and therefore cannot stand alone. It seems sound not to combine or hyphenate any two words unless there is a change of sense from that conveyed when the words stand separately.

Not Indian-meal moth or Indian meal-moth but *indian meal moth.*
Not grape-berry moth or grape berry-moth but *grape berry moth.*
Not sugar beet web worm or sugarbeet web worm but *sugarbeet webworm.*
Not European wheat stem saw fly or European-wheat stem-sawfly but *european wheat-stem sawfly.*
Not smaller European elm-bark beetle or smaller European-elm bark-beetle but *smaller european elm bark beetle.*

Another proposal I should like to see adopted is the dropping of initial capitals from common names that are derived from proper names. I can see no possible advantage in retaining them. Certainly there is little honor for person, country or geographical area in having a bug named after it. The important points of uniformity and simplicity suggest dropping the capitals. Furthermore the designation of the capital is never conveyed in *speaking* the common name. Most biologists are now agreed that the initial capital of specific names derived from proper names should be dropped and it seems to me that the same practice should be adopted for common names.

Of course these things look queer at first and I can imagine the sensibilities of some of you shrinking from:

hessian fly
san jose scale
jimson weed
bordeaux mixture
comstock's mealy bug.

But, after all, it is a matter of usage. Once they have become familiar by long usage they will be comfortable as an old shoe.

C. L. METCALF
University of Illinois

Business Sessions of the Association

THE AMERICAN Association of Economic Entomologists was organized in 1889 and has continued to function for fifty-three years. When first formed the membership was small while today it consists of fifteen hundred active members.

The policy of this association has been to hold an annual meeting, and special meetings if deemed necessary. During the course of the annual meetings one or more business sessions are held at which time the reports of the executive, standing and special committees are made. Under the present constitution, which was passed at the fiftieth annual meeting in 1937, fifty active members constitute a quorum for the transaction of business of the association.

The business sessions of the association are the most important phase of the annual meetings. This is true because policy making decisions are rendered which determine the future course that the association will pursue. It is a singular fact that these sessions attract the poorest attendance. Frequently it appears that less than a quorum of fifty are present. Such a condition is not conducive to a broad, worthwhile, continued development of this organization.

An organization to remain virile in action and virile in the minds of its membership must give to that membership a feeling of individual concern relative to its future, and a guarantee to individual expression concerning actions that affect this future. Each member must feel that he has a greater duty to the association than merely the payment of dues. At present the average member of the association assumes that the big decisions are things that are handled by a high board of strategy and merely made known at the end of each annual meeting. Doubtless it would be advisable to make every effort to break this attitude by providing a better method of expression to the membership. Let each member have a feeling of intimacy for the association and thereby create a definite feeling of responsibility for its future.

This weakness of the business sessions has been recognized and discussed by members for a number of years. Conscientious efforts have been made to stimulate a more general interest in association affairs. The open executive board meeting has had a beneficial effect. In recent years a business session has been held before the end of the annual meeting. The members continue to be absent. It is therefore recognized that these have not answered the problem.

It is even questionable whether a well attended business session would constitute a logical answer to a broad expression of attitude by the membership. This is due to the fact that attendance at annual meetings is extremely regional in character. Likewise the great majority of the meetings are held in the north east and middle west. This tends to bring about an unintentional domination of Association affairs by these regions.

A reasonable answer to this problem could doubtless be found in the creation of a senate. The membership of such a senate could consist of a minimum of one representative from each state in the United States, and province of Canada, that has members in the association; also a minimum of one representative from each section and branch.

If considered advisable additional senatorial representation could be granted based upon the total number of members in each state, province, section, and branch. Thus would be created a deliberative body that would be small enough to function effectively yet large enough to be representative. The creation of such a legislative body through constitutional amendment would be stimulating to the association and immediately give to each member a more intimate relationship with his association and a feeling of greater responsibility for its future.

JOHN T. CREIGHTON

Note:—This editorial was submitted at the request of the editor who felt that the writer had some constructive suggestions which should be presented to the Association. L. M. P.

Volume VI, Index of American Economic Entomology, has just been published. See notice in the advertising pages.